Transit Oriented Development assessment of Handen Pendeltåg Station

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**ABSTRACT**

Transit Oriented Development theoretical and practical framework represents an important tool for municipalities, private actors and citizens to enhance quality of life in urban contexts. Planning cities that encourage sustainable mobility patterns can contribute to aim at diversifying land use and making cities more accessible, safer and attractive for people. Handen has developed as a car-dependant area that is planned to growth its population and build more than 9000 new housing units by 2030 (Haninge Kommun, 2016). The TOD standard 3.0 was applied in the area around Handen pendeltåg station, to practically assess the TODness level of the area and provide recommendations to take into a consideration for future and current developments. Using the TOD standard in Handen can contribute to aim at a more sustainable growth pattern for both current and expected new citizens on the area. After implementing the evaluation system, it was found out that the best ranked variables were Compactness and Cycling. In contrast the variables that received the lowest scores were Walk, Densify, Connect, and Shift. Overall, Handen scored a Bronze level of TODness. Therefore, there are several actions that could be implemented on the study area in order to improve the TODness level. Specifically, Handen needs to diversify its land use, enhance the pedestrian network, encourage land mix use, decrease the space destined to cars and increase pedestrian connectivity, among others.

**Key words:** Transit Oriented Development (TOD), sustainable mobility patterns, land mix-use, densifying, walking, cycling, connect, shift, railway station, Handen.

**ABSTRAKT**


**Nyckelord:** Kollektivtrafikanpassad bebyggelse (TOD), hållbar rörlighetsmönster, landblandning, förtätning, gång, cykling, anslut, skift, järnvägsstation, Handen.
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INTRODUCTION
Transit oriented develop (TOD) is a concept that aims at building sustainable mobility patterns based on high synergies between land and transport planning. There are several principles that structure the TODness philosophy which can be implemented on a city through urban design practice and development policies. The main essence of this concept is to encourage sustainable means of transportation, build denser and more mixed neighbourhoods and shift away from car dependent urban areas. This concept has evolved, including more variables that add more complex and integral solutions to shift away from car dependent urban structures (Curtis, et al., 2009).

Areas around a transit station have the highest opportunities to develop high TODness levels. In particular, in Sweden, areas around railway stations represent core zones were synergies between land and transport planning could be achieved. Furthermore, within the TOD concept, transit stations represent the node area where mixed use land patterns can be implemented, as well as enhancing walking and cycling networks. Also, within TOD developments, areas around transit stations should be dense, compact and with the less space possible destined to motor vehicles (Liu, et al., 2016).

Suburban areas in the Stockholm region tend to have physical structures that make it easier for citizens to use a car rather than to use public transit, bike or walk. More specifically according to the Centre for Transport Studies of Stockholm the trip mode share of suburban areas attributes 51% of car driver trips on 2015. In contrast the inner city had a 17% of car driver share on the same year (Bastian & Böjerson, 2018). In this case is important to focus on strengthening policies, strategies and projects to discourage car use on the suburban areas of the Stockholm region.

Handen is one example of a Stockholm inner suburb that prioritizes car over sustainable mobility options (Interviews, 2019). Moreover, Handens urban structure destines a high percentage of its area to vehicle purposes. 20% of the area of study is destined to roadway area, off and on street parking (see shift variable results). Also, the existent pedestrian infrastructure could improve substantially to foster walkability on the area. Nevertheless, there is high interest from the government and citizens to reverse that trend. Planning documents such as the Stadsutvecklingsplan and the Comprehensive Plan contain strategies that plan to build higher densities, develop mix land use areas and encourage sustainable mobility modes of transport like cycling and walking (Haninge Kommun, 2016).

Additionally, Handen was chosen as one the eight regional cores within the Stockholm region (Stockholm County Council, 2017). One of the major challenges this area faces is regarding to the population growth. Handen will have around 105000 inhabitants by 2030, and this situation possess a major challenge to the municipality and other governmental agencies in terms of building new urban environments as well as densifying potential areas in a sustainable way. As the municipality plans to build more than 9000 housing units (Haninge Kommun, 2016) it is necessary to plan ahead and determine consistent urban planning guidelines that will be used to foster and promote a sustainable urban growth.

By implementing a TOD assessment in Handen this research project intends to find concrete ways of increasing synergies between urban and land planning, and therefore aim at more sustainable mobility patterns in Handen. The goal of this research was to implement a TODness assessment to Handen so that it would support decision making processes to make the area more sustainable. Also, is important to highlight that the implementation of high TOD standards can be achieved through a collaboration between public, private and non-profit stakeholders involved in the urban development processes.

This research project aims at understanding the implementation of the Transit Oriented Development principles in the area around the railway station in Handen, Sweden. Also, this research contributes to expand the knowledge about how Transit Oriented Development is being implemented in Sweden’s transportation network and land planning policies. More in detail, this research will help to understand how TOD principles could be effectively implemented in a specific area,
analyse the results and propose improvements to further contribute to transport planning and urban planning synergies and therefore thrive for planning methodologies that contribute to aim at more sustainable cities.

To develop the proposed aim, the following objectives were formulated:

(1) Implement the Transit Oriented Development Standard 3.0 around the chosen area of study.
(2) Analyse the results of the evaluation performed on the first part of the research.
(3) Propose improvements on the area of study in order to aim at a more sustainable neighbourhood aligned with the TOD principles.

Within the first objective the assessment evaluation method was implemented in a 500 meters radius surrounding the area of Handens pendeltåg station. All 8 variables and 25 parameters included in the TOD standard 3.0 were evaluated using spatial analysis tools as well as observations, satellite images, pictures and interviews. Regarding the second objective, the evaluation was applied, and the classification of the chosen area was made accordingly to the three different categories; Gold, Silver and Bronze. To achieve this objective, the results were analysed throughout the document, and then summarized on the last section. In this case the interviews, observations and literature review were used to understand the results. The analysis of the results was made to understand the current situation of TODness in Handen and so that it could be used as a base analysis for the planning methods around the area of new stations and the renovation of the other existent pendeltåg stations in the area. The general overview of the results is related to the relation between urban and transport planning on the area around the pendeltåg station.

The third objective was achieved through the suggestion of improvements of the variables that did not achieved the highest score. To accomplish this objective there were performed spatial analysis in order to physically place the areas in which the proposed improvements could be implemented. Within the performance of the assessment it was also suggested how each of the variables could reach a 100% of the points assigned to each category. At the end of each variable is stated the amount of points reached per category and at the end of the section one it can be seen the total score of the TOD assessment for the Handen pendeltåg station.

The research question that guided this master thesis was: In what extent is Handen pendeltåg station and its surrounding area implementing transit-oriented development principles aiming at higher synergies between transport and land planning? The purpose of this research question is to stimulate a reflexion around the synergies between the land and transport planning dimensions in Handen and provide analysis guidelines aiming at the improvement of the implementation of the TODness into the planning process of current and urban developments around pendeltåg stations.

This master thesis is divided in six parts. The first part introduces the research topic, describes the objectives and outlines the research problem. The second part describes the methodology of the research, it describes both the qualitative and quantitative methods used to develop the research question and objectives. It also describes the TOD indicators used to perform the assessment in Handen. The third part of the thesis, explains and describes the theoretical framework. It introduces a timeline of the concept as well as mentions and describes the most important notions and concepts within Transit Oriented Development and the TOD standard 3.0. The fourth part goes on into applying the TOD assessment in Handen, it shows and describes the results of the TOD assessment of Handen. This section uses the maps developed with Qgis, as well as pictures taken by the author, reference pictures and Google satellite images. The fifth part focuses on discussing and analysing the results, this part presents a summary of the findings as well as it describes the most important findings. Finally, the sixth part shows the references, the list of figures and tables as well as the questions that were used during the interviews with the urban planners of Haninge Kommun.
THEORETICAL FRAMEWORK
2.1 Definitions of TOD

Transit Oriented Development is a comprehensive theoretical framework, urban design practice and development policy that has evolved since the 1990’s when it was first formulated. Peter Calthorpe first explored and revised this idea. He conceived this concept under a notion of modern planning methods that aimed at building sustainable communities supported by a strong social and environmental background. Also, according to Carlton, Calthorpe was inspired in earliest philosophies that reinforced the synergies between development and transit (University of California, 2007).

Nonetheless, earliest thinking was focused on the influence of transit and real estate development without going further into other dimensions. Notions that supported car dependent societies were developed in the United States. As Carlton describes in his research: Histories of transit-oriented development perspectives. Carltons research showcases some examples on how some cities in the U.S developed their urban growth along car streets, parking areas and car-oriented infrastructure. This period was known as “Auto oriented transit” and its placed between 1945 and 1970. The period during 1970 and 1980’s was characterized by the concept of “Transit related development” which was mainly developed by a partnership between transit agencies and private real estate developers (University of California, 2007).

After this period, other thoughts started to arise were densities, pedestrians and affordable housing were also important to achieve higher synergies between transport and land planning. In 1993, Robert Cervero that had explored the TOD concept, released a research called: Transit – Supportive development in the United states. In this research he describes transit supportive developments included urban design guidelines were a varied kind of factors were considered. Factors such as: higher densities, land mix, walking distances, institutional amenities and open spaces were the core values incorporated on developments in Virginia and Maryland in the United States during the late 90’s (Cervero, 1993).

Moreover, Calthorpe’s professional carrier focused on developing notions related to sustainable communities, environmental design and pedestrian pockets, among others. All these notions had the core value of designing environmentally friendly and car free societies that provided efficient transit systems for its citizens. Most of the transit systems networks in Calthorpe’s work were related to rail-based projects. He developed a project called LUTRAQ were he linked the concept of pedestrian pockets and rail corridors. This project was implemented in Oregon, US. The main objective of this project was to: “to promote development patterns that reduce land consumption, vehicle trips, and air pollution nationwide” (Calthorpe, 1993).

Both previously mentioned theoreticians work was complementary, Robert Cervero and Peter Calthorpe contributed immensely to the formulation of the TOD notion. More in detail, as Carlton describes when discussing about the origin of the term TOD: “Cervero suggested “Transit Supportive Development” but Calthorpe felt that the term he had discussed with Sacramento planners, “Transit-Oriented Development,” had a preferable acronym that would “help build a better brand.” He used the acronym TOD in the New York Times article, and it was firmly set in the design lexicon (University of California, 2007). Calthorpe then summarized his previous related work with TOD into his book called: “The next American Metropolis”, the key components of this concept were outlined by Carltons text. They are: “(1)Organize growth on a regional level to be compact and transit-supportive (2) Place commercial, housing, jobs parks, and civic uses within walking distance of transit stops (3) Create pedestrian-friendly street networks that directly connect local destinations o Provide a mix of housing types, densities, and costs (4) Preserve sensitive habitat, riparian zones, and high-quality open space, and (5) Make public spaces the focus of building orientation and neighbourhood activity” (Calthorpe, 1993).
There are also prior TOD examples in Sweden. Valingby was designed as a garden neighbourhood next to the railway infrastructure. This was the so-called first “ABC” area (arbete-bostad-centrum) were residential uses were built alongside working places and commercial areas. This example was known as a progressive approach towards what would be later called TOD (Hadenius, 1999).

Furthermore, the research conducted by Stojanovski et al. explains the historical context of TOD related projects in Sweden. They describe how urban growth was linked to transportation patterns and discuss the ABC principle in this context: “The ABC principle was a Swedish response to the modernist functional city modified by the neighbourhood principle of functional containment that arrived with Lewis Mumford’s Culture of cities (Nyström and Lundström, 2004). The principle was actualized either as tunnelbana suburb or a satellite city, a cluster of suburbs” (Stojanovski, et al., 2012). In this case trams and light railways are seen as a catalyst tool to aim at sustainable development patterns. Likewise, within Stockholm’s urban history it has been demonstrated that urban growth is usually concentrated around transportation structures that have shaped the city as “suburban pearls” and “urban nucleuses” that support wide public transportation mobility patterns (Stojanovski, et al., 2012). Also, the concept of “city of pearls” was explained more in detail by Stojanovski’s research about the urban morphology of public transport system. He described how Stockholm developed around a transportation network where railways structuralize the system and buses “elongate and interweave its urban cores into corridors” (Stojanovski, 2013). Figure 1 illustrates the concept of “city of pearls”.

The TOD concept has evolved, and it varies upon the context in which it is used. In some of the United States governmental agencies that have used the term, there are some common notions that according to Cervero can be defined as: “a pattern of dense, diverse, pedestrian-friendly land uses near transit nodes that, under the right conditions, translates into higher patronage” (Cervero, 1993). Also, other concept which included a wider range of elements was adopted by the Washington Metropolitan Area Transit Authority, they defined TOD as: “Areas near transit stops which incorporate the following principles: reduce automobile dependence; encourage high shares of pedestrian and bicycle access trips to transit; help to foster safe station environments; enhance physical connections to transit stations from surrounding areas; and provide a vibrant mix of land use activities” (Cervero, 1993). This concept includes the idea of linking the transit station to the urban tissue through the support of mixed land patterns and sustainable mobility options for citizens.

This view can also be complemented with the theoretical framework developed by Carey Curtis, Lucas Bertolini and John Rene on the book Transit Oriented Development: making it happen. They discuss about the complexity of integrating transport and urban development within urban governance due to the various kinds of actors involved, as well as the different dimensions involved in developing TOD notions. Also, they described how stations can be understood both as a node and a place, which is a useful notion to understand the role of the station on the urban structure.
Also, Curtis, Bertollini and Rene gave the example of the compact city policy versus the Transit-Oriented Development model, showed on the figure (see figure 2). In this case it is exemplified with the sketch on the left, how cities in some cases grow next to other urban conglomerates without effectively encouraging sustainable mobility patterns. In this case, the sketch on the left shows how new urban settlements were placed next to motorways and close to the previous urban structures. On the other hand, the right sketch illustrates how new urban settlements can be placed next to railway stations and therefore, prioritize public transportation traffic (Curtis, et al., 2009).

Furthermore, Cervero includes other dimensions within TOD. This theoretician emphasizes on the importance of smaller units of analysis such as blocks. He argues that the way blocks are structured in future urban areas is key to determine the accessibility of pedestrians and bicycle users, and how easy it would be for those actors to navigate the road network. Adding to that, the shape of the urban structure can influence the car use. He states that shorter distances for pedestrians and adequate networks for bicycle users along with an appropriate land mix use can shape cities into a more sustainable future. To go over the main points of Transit Oriented Development, Cervero summarizes that TOD policies: “promote more walking and transit riding and less driving; pedestrian-friendly designs such as safe and attractive sidewalks; small city blocks and a highly connected grid like street network; mixed land uses that place many destinations close to each other, including small storefront ground-floor retail in commercial districts; sufficiently high densities to justify high-quality and frequent public transport services; and community hubs and civic places that promote social interaction and a sense of belonging” (Cervero, 1993).

Other complementary notions around TOD, have been summarized and explained by researchers Rafaello Furlan et al. They stated “Scholars argue TODs can increase access to public transportation, workplaces, educational institutions and other facilities by promoting transportation options to households. Destinations, Distance, Density, Design, Diversity and Demand Management are the well-known six Ds, which are consider as the basic principles providing the maximum benefits of TOD for communities (corridors of opportunity)” (Furlan & AlMohannadi, 2016). As a result, the implementation of those principles aims at encouraging pedestrian traffic in the surrounding areas of transit stops, creates a safe environment and increases public transportation ridership (Furlan & AlMohannadi, 2016).

Spatially on the urban structure the TOD model has been explain extensively by Peter Calthorpe. Researchers Mingqiao Zou et al explained the TOD morphological model based on Calthorpe’s illustrations. Figure 3 shows
a TOD area which is based on elements such as: public transportation station, core commercial, office/employment area, TOD residential area, secondary area and public open space (ZOU, et al., 2014). This model explains that within the TOD structure the areas closer to the station are the ones that should have higher development, specifically concentrated within a 500 meters radius. Land use intensity starts decreasing 600 to 1000 meters away from the transit station. This model also contributes to understand the importance of mixed land use within this concept. There is a high mix between residential, commercial, offices and transportations infrastructure. All these elements aim at reducing travel demand (ZOU, et al., 2014). Higher intensity use areas next to transit stations are also known as urban cores, urban cores have different types and vary according to its function “there is a desirability core (Stoianovski 2013a), the most desirable TOD zone in the center. The morphological effect on architecture and cityscapes is visible firstly in the TOD CORE zone. The TOD CORE zones are tentative and question the traditional urban design heuristics about walking distances” (Stoianovski, 2015). These core zones areas around a transit station which are reachable within walking distance stand as a valuable element to foster a sustainable urban land use pattern.

Within TOD there are numerous factors discussed by several theoreticians and practitioners. Some of the TOD factors that have been more widely discussed are mixed land use, affordable housing, density and walking. For Mixed land use, several studies associates land use to public transport ridership. According to Sarkar et al “land-use mix was found to be strongly associated with the choice preference of public transport. The coefficients were positive for public and nonmotorized modes, which imply that the trip makers residing in the areas with mixed land use prefer public and nonmotorized travel modes” (Sarkar & Chunchu, 2016). This demonstrates that mixed land use can be considered an important factor to aim at TOD development patterns, as its been proved that higher mixed-use land patterns discourage the use of motorized vehicles to transport and encourage walking and cycling.

Affordable housing is other of the topics that have been widely related to TOD. In this regard, the research developed by Pal explores the notion of developing affordable housing projects close to transit stations. Specifically, railway stations so that citizens would have access to public transportation options. In that way “easy access to multiple modes of public transit would increase a household’s budget for housing by eliminating the financial burden of owning a car” (Pal, 2018).

Likewise, Pengjun et al studied the relationship between the citizens patterns to choose the residential location and the housing prices. They stated that “When it comes to residential location choice, land use policy should be assisted by housing policy to encourage passengers to choose to live near metro station areas. The high housing prices nearby transit stations may force people, in particular, low-income people, to live far away from metro station areas” (Pengjun, 2018). In this sense, promoting affordable housing residential projects can contribute to TOD principles by aiming at a social mix by the income level of the area and increasing synergies between housing policies and transportation planning.

Concerning the relationship between density and TOD, Peter Calthorpe has studied the importance of having higher densities in a range of 0 to 300 meters around a transit station. Also, Calthorpe suggests that the average population density for TOD community is 8100 person/km2 (Calthorpe, 1993). This factor influences TOD in the sense of the importance of the high level of land use intensity of an area around a transit station.

Regarding walkability and TOD there are several theoreticians and practitioners that have discussed about promoting walkability around transit stations. One of the most known authors that have analysed this topic is Jan Gehl. He focused one of his publications on how to aim at more walkable cities in Australia. Gehl stressed on the notion of how walkability is a key factor to increase benefits on cities. Walkability contributes to the economy, social and environmental spheres of a city. But it also poses a challenge to planners in terms of achieving walkable and attractive areas for citizens both on the city and the suburbs (Matan, A. & Newman, P., 2012). Furthermore, aiming at walkable cities is intrinsically linked to urban form.
Theoretician Jeff Speck developed a research where he describes rules to make a city more walkable. Amongst the most important steps Speck describes, there is the discussion about the role of smaller blocks on increasing pedestrian security, and also higher economic opportunities (Speck, 2018).

Several efforts through history have been made to encourage urban growth using non car dependent structures. For example, the book the new transit town explores several best practices in TOD development throughout the United States. They mention in one of the case studies, the TOD project undertaken in Arlington, Virginia. This was a low-density area where the TOD principles implementation resulted in a successful redevelopment process for the area. Also another example in Dallas illustrated how the TOD principles foster sustainable mobility patterns and encourage public transport use in suburban areas (Dittmar & Ohland, 2004).

Transit Oriented Development is a concept that contributes to design less car dependent societies and urban area. Within the theoretical framework of Transit Oriented Development, the Institute for Transportation and development policy (ITDP) formulated a standard that can be used to measure the TODness of a study area. The ITDP is an organization that promotes the use and implementation of TOD policies and best practices to actively reduce car use in cities. This tool within TOD proposes to implement practical measurement parameters in already built cities as well as in future undeveloped areas to discourage car use and promote sustainable mobility alternatives. This tool is called the TOD standard 3.0. The following section will describe the components, variables and parameters used by this TOD standard.

### 2.2 TOD standard

The TOD standard is a quantitative tool that facilitates the implementation of TOD principles in the current and future urban contexts. This standard operationalizes the TOD principles and puts it into practice. The TOD standard 3.0 is a key tool to further aim at more efficient transportation networks and sustainable urban planning methods. According to the TOD standard 3.0: "This tool may be of use in analysing and evaluating the potential and the challenges in the existing built area around transit stations. It can help prioritize action to mend gaps or to focus investment on the areas promising shorter term success at the transportation corridor, city, or metropolitan urban area level” (ITDP, 2017). This standard is based upon a scoring system that makes its implementation and evaluation more accountable. The TOD standard scoring system distributes a total of 100 points over 25 different criteria divided in the 8 transit-oriented development principles; walk, cycle, mix, connect, shift, densify, compact and transit. This scoring system intends to show the overall result linked to an area but also the score that each of the criteria has. Overall, the score system awards different scoring categories. The three possible scoring results are: bronze, silver, and gold status, which vary according to the requirements of each category (ITDP, 2017). Subsequently the 8 principles will be explained and described.
2.2.1 Walk

More in detail the first principle focuses on walkways and crosswalks, this principle is divided in 5 subcategories: Quality of walkways, quality of crosswalks, visually active frontage, physically permeable frontage and shade and shelter. The general objective of this principle is to aim at a safe and accessible pedestrian network. Within the walkways sub-criteria, the variables taken into consideration are the number of walkway segments and the qualification of each of the segments. The qualification of the segments varies upon the existence of barriers and completeness of the pedestrian network. Figure 4 shows the scoring system for this principle (see figure 4).

The second sub criteria evaluates crosswalks. In this case the variables that are included on the assessment are the quantity and quality of pedestrian intersections. Within this section is important to observe within the intersections the number of barriers for people with disabilities and, count the safety crossings that include elements such as refuge passages (See figure 5).

The third sub criteria was the visually active frontage which focuses on the percentage of walkway segments with visually active facades. Within this parameter the concept of visually penetrable frontage is being used. This concept specifically refers to: “partially or completely transparent windows and materials along the length of frontage at any point between ground level and 2.5 meters (m) above ground. In this definition, residential building windows with ledges just above pedestrian eye level are acceptable” (ITDP, 2017). Figure 6 shows the scoring system for this parameter (see figure 6).

The next sub criteria within the walking evaluation criteria is physically permeable frontage. This parameter studies the quantity of the frontage that intersects with building entrances were general public is allowed. This includes the intersection with commercial uses in general. Some examples would be lobbies, parks, plazas etc. And excludes the intersection with “non qualifying entrances” such as storage areas, garages and driveway entrances. Figure 7 explains the scoring system in detail (See figure 7). This sub criteria is useful to potentially analyse the relation between the walking segments and the commercial and open areas of a neighbourhood. In this sense, recommendations can be made regarding the synergy between the mentioned dimensions.

The fifth sub criteria considers the shade and shelter surrounding the walkway segments. This refers to urban structures and furniture that provides shelter from weather conditions to pedestrians. The TOD standard includes elements such as drinking fountains, public toilets and named them “climate adequate elements”. In this specific case this sub criteria needs to be adapted to Swedish context and consider elements within winter design principles that can be found on the urban structure of the area of study. On the following illustration (see figure 8) the scoring process is showed. This sub criteria can be useful to analyse and provide recommendations regarding the inclusion of winter design elements for
public space such as all year around patios and public spaces, pocket parks, narrow towers to allow sunshine through, snow mound for playing/blocking the wind, etc (Edmonton city, 2016). The walking criteria is a useful tool to quantify important elements within the pedestrian dimension. Likewise, this tool helps at qualifying the physical structures of an area of study, being able to give specific recommendations on how to improve the pedestrian network. Elements like the completeness of the walking segments are crucial to understand how pedestrian move around the city. On the other hand, elements such as crosswalks, visually permeable frontage and physically permeable frontage are vital to understand the routes and paths pedestrians use to reach specific areas of interest. Lastly, within the sub-criteria of shade and shelter is important to understand how pedestrians are affected by weather conditions and how the city structure and furniture responds to that.

2.2.2 Cycle

The second criteria within the TOD standard is cycle, its main objective is that the cycling network is safe and complete. This element is subdivided in four sub criteria; cycle network, cycle parking at transit stations, cycle parking at buildings and cycle access in buildings. The first sub-criteria have to do with the inventory of all street and path networks on the area of study and then classify them according to the proximity of the buildings within the surrounding area and accessibility. Figure 9 shows the specific evaluation measurement used for the scoring system (See figure 9).

The second sub criteria evaluate the transportation stops around the area to analyse into what extent those platforms facilitate multimodality and cycle storage spaces. In this case it is required to identify the “cycle racks” 100 meters around the specific transportation station and qualify them according to the conditions in which bikes are stored. Figure 10 shows the specific grading score for this sub criteria (See figure 10).

The third sub criteria within this category is the cycle parking at buildings, in this case it is needed to quantify all buildings around the study area and measure how many of those have cycle parking facilities. Figure 11 shows the exact score method for this sub criteria (See figure 11). This tool is useful to provide recommendations upon the physical facilities provided for bicycle users on the residential areas. This ratio is useful to understand how the nonmotorized vehicles mobility is being prioritized on certain areas.

The last sub criteria within this category is the cycle access to buildings. This category has a similar objective as the precedent sub criteria. The objective is to analyse into what extent a building is accessible for a bike user. On the other hand, the methodology varies, it requires to go through the bylaws or lease agreements of the residential buildings of the area and analyse if the cycle access is required or prioritized. Figure 12 shows more in detail the scoring system (See figure 12).
The cycle parameter is a helpful tool to understand how the cycle network is placed in relation to the residential buildings around the area of study. Urban areas that prioritize bicycle mobility could include some of the physical structures mentioned on this dimension, specifically, elements like cycle parking and cycle accessibility to buildings. Numerous elements are involved in bicycle traffic; therefore, the quantifying process should also be complemented with the qualifying characteristics that bike users need in order to aim at a more accessible, safe and complete bicycle network.

2.2.3 Connect

The third principle is Connect. This variable is subdivided into two subcategories. The first is the size of the block and the second one is connectivity. The general objective of this parameter is to measure the accessibility and connectivity of the road network. The first subcategory measures the length of the longest block. The procedure in this criteria relies on quantifying all the blocks and then measuring the size of each segment. In this case, more scoring points are given to the blocks that are shorter because this type of urban form facilitates pedestrian mobility. The ITDP argues that shorter blocks favour connectivity and walkability for citizens. The specific scoring system is detailed on figure 13 (See figure 13). The following parameter of this criteria is the prioritized connectivity, within these criteria the main objective is to compare the weights on the whole network of the intersections between motorized vehicles and pedestrians. The procedure relies on performing a ratio between the number of motor vehicle intersections and the number of pedestrian intersections. The following figure (figure 14) shows the scoring system more in detail.

Within the analysis of the urban form is possible to understand the level of priority of non-motorized vehicles. The following image shows an example of an area where pedestrian traffic is prioritized over motorized vehicles traffic.

2.2.4 Transit

The fourth principle is transit. This category represents the proximity in walking distance to the nearest transit station. In this case, the walking distance proximity towards a station is analysed. This criteria does not give any points to the scoring system. The transit variable represents a given condition that should be met in order to be able to analyse all the other categories. The parameter relies on having a transit station within 1,000 of walking distance to the farthest building in the area. The following
2.2.5 Mix

The fifth principle is mix. This criteria is subdivided into six subcategories. The first is complementary uses, then access to local services, access to parks and playgrounds, the fourth one is affordable housing. The fifth one is house preservation, the sixth one is business and services preservation. The general objective of this parameter is to plan urban spaces adapted for a mix on income, demographics and uses.

The first category, complementary uses, focus on quantifying the residential and non-residential uses on the same area. More points are given to areas that have higher percentage of mixed land use. The method consists on finding the mix ratio between the variables of residential and non-residential use. For example, when the same type of land use has more than 80% of the total floor area on the area of study the evaluation parameter attributes 0 points. And on the contrary, when the total of the floor area has a predominant use of 50% or 60% the parameter attributes 8 points which is the highest. The following figure shows the scoring criteria more in detail (See figure 16).

The second parameter is access to local services. This parameter measures the percentage of buildings that have proximity to the following amenities: primary schools, healthcare service or pharmacy, and source of fresh food (TOD, 2015). The procedure requires mapping the building entrances, the primary buildings, the sources of fresh food and the elementary schools along the healthcare centers or pharmacies. The given points in this category vary upon the quantity of types of local services that are placed and accessible to the buildings surrounding area. Fewer points are given to areas that have a low percentage of buildings that have access to local services within walking distance. The next figure shows the scoring system for this specific parameter (See figure 17).

The third sub criteria is access to parks and playgrounds which measures the percentage of buildings located within a walking distance to areas such as parks or playgrounds (ITDP, 2017). The procedure of this calculation is mapping all the buildings and the parks and playgrounds. The scoring system gives 1 point if 80% of buildings or more are within 500 meters of these mentioned areas. The following figure shows more in detail the scoring system (See figure 18).

The fourth sub criteria is affordable housing, this parameter measures the percentage of the housing areas that are considered as affordable. Affordable housing are considered as: “Affordable housing rent is below 30% of the mean income in the relevant income category” (ITDP, 2017). Within this section it is required to do a ratio between the residential housing and the affordable housing area. Higher scores are given to areas that have higher percentage of affordable housing. The next figure shows more in detail the scoring system (See figure 19).
The fifth sub-criteria is housing preservation, in this parameter the objective is to quantify the percentage of housing units that were relocated within walking distance if they were part of infrastructure projects that required relocation. In this case is important to analyse on going housing or commercial projects in the area of study, the next figure portrays the method of scoring (see figure 20). The next sub-criteria involve a similar approach. The sub-criteria number five, business and services preservation propose to quantify the percentage of local services that are relocated within a walking distance from the previous location. In this case is important to identify the businesses that fit into the criteria and quantify the number of those that got relocated within a walkable distance. The figure 21 shows more in detail how the scoring system works for this parameter (see figure 21).

![Figure 20 existing housing source (TOD Standard)](image1)

**2.2.6 Densify**

The sixth principle is Densify. This criteria is subdivided into two subcategories. The first one is non-residential density, the aim in this subcategory is to measure the non-residential density and compare it to a similar area. The objective is to quantify the non-residential floor area and the number of visitors on both areas and extract some best practice guidelines. The project that the study area is being compared to should be considered as a best practice project from which lessons can be learned and baselines can be extracted. The following image shows the evaluation process in detail (See figure 22).

The second sub criteria is residential density, the aim in this subcategory is to compare a best practice project in a similar area and analyse it according to its residential density. The steps of this calculation are to estimate the unit density of the area and compare the two projects. This subcategory has a similar approach than the previous parameter. On the following image the evaluation criteria is explained more in detail (see figure 23).

![Figure 21 existing services source (TOD Standard)](image2)

![Figure 22 non-residential density source (TOD Standard 2017)](image3)

![Figure 23 residential density source (TOD Standard 2017)](image4)
2.2.7 Compact

The seventh principle is compact. The main objective of this category is to plan for cities where it is possible to make short commutes. This category prioritizes the closeness of the built environment and the convenience of shorter travels for citizens. This criteria is subdivided into two subcategories. The first one is urban site. This parameter measures the percentage of developable area within the surrounding area of the transit station. This subcategory raises the awareness of the importance to develop the areas around transit stations. In this case most points (8) are given to the areas that developed more than 90% of the developable areas. The following figure shows the scoring criteria more in detail (See figure 24).

The second subcategory is transit options, which has as a main objective to identify all the transport network system of the area. The process of measuring this sub criteria relies on quantifying the high capacity regular transit services within walking distance but excluding the main station that was subject of analysis in previous parameters. The following image shows the scoring system in a more detailed way (See figure 25).

![Developable Sites Table]

*Figure 24 developable sites source (TOD Standard 2017)*

![Transit Options Diagram]

*Figure 25 transit options source (TOD Standard 2017)*

2.2.8 Shift

The last principle is shift. The main objective of this category is to “increase mobility by regulating parking and road use” (ITDP, 2017). This criteria is subdivided into three subcategories. The first subcategory is off street parking, which aims to estimate the total off street area with a parking use in comparison with the total built area. This parameter gives more points to the areas with less percentage off street parking area compared to the total area. Figure 26 shows the scoring system more in detail (See figure 26).

The second sub criteria is driveway density, this parameter measures the average of driveways that are within 100 meters of the block unit. The measurement method requires to quantify the number of driveways that intersect a walkway and quantify the total length of the block unit. Then it is required to estimate the ratio between these two. This subcategory gives more points to the areas that have 2 or less driveways per 100 meters of block unit. Figure 27 details the scoring system (See figure 27).

The third sub criteria is roadway area, this parameter measures the “total road bed area used for motor vehicle travel and on street parking as percentage of total development area” (ITDP, 2017). The measurement method is to quantify the area of traffic lanes, on street parking and then add these two variables. After that is required to quantify the area of the built environment and divide it by the result of the sum. And lastly, it is needed to calculate the percentage of land paved motor vehicle on street parking. Figure 28 shows more in detail the scoring system for this parameter (See figure 28).
The eight principles described above promote and enhance “spatial configurations that enable high-quality, car-free lifestyles” (ITDP, 2017). Specifically, the TOD standard is focused in offering assessment to the areas located within a walking distance of a high capacity transit mode. The TOD standard was formulated so that municipalities, NGOs and different governmental authorities could evaluate crucial aspects through a metric system that allows to monitor the progress in the implementation process of this framework.

The TOD standard is formulated as a tool that can be used to analyse built environments as well as planned projects in order to identify gaps or elements of improvement. After the revision of this tool it was decided that the TOD standard offered the tools to make a comprehensive TOD assessment on an area around a railway transit station. Subsequently this theoretical framework was adopted to develop the TOD evaluation of Handen.
METHODOLOGY
3.1 Research methodology

The methods used in this research were a combination of qualitative and quantitative research methods that intended to fulfil a comprehensive TODness assessment on the area of study. The methods that were used complement each other regarding their advantages and limitations. The quantitative method used gave the spatial results, whereas the qualitative methods were useful to understand and interpret the spatial study that was performed. The methodology builds upon the three proposed research objectives.

The first method used was mapping. Geographical Information Systems are a useful tool to relate geographical information with variables within Urban Development. According to Esri, Spatial Analysis refers to, “The process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques in order to address a question or gain useful knowledge” (ESRI, u.d.). In this case, the Qgis software was used to score the variables that resulted from the TOD literature review. The indicators used on this scoring system included variables such as: density, mixed land use, walkability, cyclability, parking space and social housing, among others. Each of the variables analysed were assessed using the Qgis software, complemented also using statistical tools to retrieve more useful information to understand the spatial results. The statistical analysis was used to build up the ratios needed to unveil the relationship between the analysed variables. The majority of the ratios were showed as percentage while others were shown in decimals. The ratios that were expressed in percentage were: cycle parking at buildings, complementary uses and affordable housing. Whereas, the ratios represented in decimal were driveway intensity and prioritized connectivity.

The limitations within this method rely on the rigidity and inflexibility that represents the process of data mining and geo-processing, which may result on the exclusion of important information outside that range of analysis. Also, this information when analysed without contextualization or further explanations may lead to false conclusions. To solve this specific limitation, it is important to combine the first with the following research method described below.

The second method is Interviews. This qualitative method allowed further analysis of the spatial information constructed using the first method. The interviews were conducted to Urban Planners working on the Urban Planning department in Haninge Kommun. This research used semi-structured interviews to 4 individuals of the mentioned municipality. Interviews were developed and processed and were part of the analysis part of the research. A total of 13 questions were asked to each of the planners, these questions were answered individually in a time lapse of about one hour for each one of the sessions. The information retrieved on these interviews was essential to proceed with the research project and to further understand the study area. With the results of the interview it was possible to compare opinions about the mobility patterns and the visions and plans on how to solve the main challenges encountered. The limitations within this method are that the answers that result from the interviews may not reflect an objective opinion based on their role as planners, but rather as a perception of the area as citizens that live and work on the area. To solve this limitation, the statements that were included in the text were the common remarks between the people that were interviewed.

The third method was observations. A direct on-site observation was performed, in this regard the text by Smith was revised and some considerations of onsite observations were retrieved. It was important to understand the procedure of observing, describing, analysing and interpreting the field work (Smith, 1978). Specifically, structured observations were used to quantify the bike parking spaces on the sample area within the analysis of the bike variable. In this case, the area was visited with the use of a map and the locations of the bike parking and bike access to buildings were identified. Also, unstructured observations were used to walk around the chosen area of study and analyse how easy was it to walk and get
from the pendeltåg station to the office area next to it was well as to one of the residential areas. The limitations within this research method had to do with the physical effort that was implied on walking the whole area and locating each of the elements that needed to be observed. Also, during one of the observations the researcher felt unsafe because there was no one on the streets and it was getting dark. These limitations were solved by addressing smaller areas at the same field visit and trying to perform the visits on the morning hours.

The fourth method used was online satellite imagery. According to Monkkonen, Google satellite image analysis have become a useful tool for urban planning practice and research. This method consists of using Google interface to analyse the study area (Monkkonen, 2008). The method was used to analyse variables using satellite pictures of the area and sample areas. Specifically, this method was used to analyse the variables of qualifying intersections, qualifying walking segments, qualifying, public walkways, visually active frontage, cycle parking at buildings, complementary uses, business and services preservation and roadway area. The advantages of this method were that it was used to import data from Qgis into google maps and perform deeper spatial analysis overlaying the satellite images and the Qgis layers. Also, this method saved time in the sense of how fast it was to analyse bigger areas in less amount of time. The limitations on this method have to do with the uncertainty of the date of the data collection, according to Mokkonen: “data is presented without clear dates. Thus, its usefulness is determined by the time frame of analysis - as the period of time gets shorter, the uncertainty surrounding the end date becomes increasingly problematic” (Monkkonen, 2008). This limitation was overcome by using the satellite images and analysis as a reference and further combine it with the mapping method.

Regarding data collection, some of the spatial data needed was provided by the municipality with the help of Haninge Kommun planning department. Some other data was collected using public sources of information such as Open street maps. Although due to the scale and complexity of some of the information, most the data needed to implement this methodology had to be developed or complemented by the researcher. For instance, the data used to develop the walkability analysis was made using the official inventory and then it had to be complemented by mapping other segments that were not included in the original inventory. Into the same extent, there was some information that was not found. For example, it was not possible to find data about affordable housing policies or quantity of affordable housing units for the area. In this case the data was retrieved by unofficial sources of information and it was combined with interviews.

It was also important to make a comprehensive literature review to understand and analyse the TOD variables and parameters. Figure 29 summarizes the most important steps followed during the research (see figure 29). Firstly, it was important to make a comprehensive literature review and research. After that, it was necessary to make a sufficient data
collection to measure all 25 parameters. Also, study visits took place during the period from January until April. Then, the data was processed, and the majority of results were produced. After that the data was analysed and complemented with interviews to 4 of the urban planners in the Planning department of Haninge Kommun. After gathering all the information that was collected the overall evaluation and recommendations were made. The last part of the research focuses on the final reflections, discussion and further research.

The specific area of study was chosen upon the eligibility criteria explained on the measurement parameters, therefore, a radius of 500 meters around Handen pendeltåg station was made. The area selected within that radius was included into the analysis.

3.2 Indicators from TOD standard used as methodology

The TOD standard was used to measure the TODness level of the area surrounding Handen pendeltåg station. All indicators were used on the TOD assessment of Handen. The standard includes 8 different principles and several parameters to measure each one of them. The eight principles are: walk, cycle, connect, transit, mix, densify, compact, and shift. Figure 28 showcases all the indicators that were used to perform the TOD assessment of Handen (See figure 30). The principles of Walking and Cycling aim at reducing barriers for walkers and facilitate intersections and crossings for pedestrians in order to foster sustainable mobility alternatives. The third principle is Connect, and it emphasizes on the importance of enhancing pedestrian connectivity within the study area. New and existing areas ought to prioritize connectivity within walking distance. Likewise, the principle of transit stresses in the importance of the proximity of transport network stations and public travel modes to residential buildings. In this case, is important to highlight how crucial is the closeness factor from the stations to the residential areas.

The fifth principle is Mix. This principle gives a higher score to those areas with more diversified land uses and with higher social mix. This principle stands for the importance of providing different urban services to citizens within the same area so it would result in a more active and vibrant space as well as achieving higher diversity in income ranges and demographics. The sixth principle is Densify. This principle focuses on the importance of densifying the areas around transport networks. This principle attributes higher points to those areas that include higher densities in the 500-meter radius around a high capacity transportation system. The principle number seven is Compact. This principle emphasizes on the importance of short travel distances for citizens living or visiting the area. The eight principle is Shift, which stresses in the importance on minimizing the space for motor vehicles use aiming at the decrease of private car use.
RESULTS AND TOD ASSESSMENT IN HANDEN
4.1 Testing the TOD methodology in Handen

Haninge is a municipality located on the south of Stockholm city in Sweden. It has approximately 87,000 citizens, and according to the comprehensive plan (2016); “Haninge is expected to increase its population to just over 105,000 inhabitants by 2030. To be able to offer attractive homes for these new inhabitants, we need to build at least 9,000 new homes in an expansion rate of at least 600 homes per year” (Haninge Kommun, 2016). This area in known for having a vast green and blue infrastructure which provided recreational services for people living in Stockholm but also, it has developed as an industrial and commercial area within the region.

On the Stockholm’s regional level, one of the key initiatives that embodies the interests of shifting from a car dependent society and meet the fossil fuel free goals are the RUFS (Regional development plan for the Stockholm region). This policy document mentions the importance of building sustainable cities through “resource efficient and resilient region with no climate affecting emissions, aiming that at least 70% of all journeys within the country shall be made on foot or using a bicycle or public transport” (Stockholm County Council, 2017). The RUFS included Handen as one of the eight regional cores where the region is planning to grow. Along with other seven areas, Handen was recognized as a potential place to further develop residential, commercial and industrial uses that would boost Stockholm’s region social and economic spheres. Figure 31 illustrates the eight regional cores (See figure 31).

Some of the TOD principles have been taken into consideration in some planning tools in Haninge. For example, the Stadsutvecklingsplan of 2016 includes the principles of public transit closeness and mixed land use. In this respect, one of its main objectives relies on building new areas close to transit stations, with higher densities, diversified land use areas and vibrant new spaces. It is stated on the Stadsutvecklingsplan: “we want to build close to public transport and service to stimulate sustainable travel and service, different types of urban development - the development towards a vibrant and mixed city takes place through new exploitation, transformation and densification. Place to live, work and create - we want to create the conditions for the mixed city where housing, business, creative activities and education co-exist side by side” (Haninge Kommun, 2016).

Also, Haninge Kommun has set up working objectives to enhance pedestrian and cycle traffic, the Stadsutvecklingsplan states: “we want to prioritize walking first because it promotes both the environment and public health (...) we want to create a well-functioning network of cycle paths for both commuting and recreation (...) we want to create clearer hierarchies and a fine-meshed structure with new road links that make it easier to orient themselves (...) we want to transform wide streets into more intimate rooms with more content and space for people” (Haninge Kommun, 2016).

The vision 2050 of Handen includes specific higher densities, mixed land uses and pedestrian networks. Figure 32 shows the different planned densities in Handen, which includes buildings up to 6 floors Figure 33 shows the diversified mix land use planned for Handen.
Other researches have explored TOD principles in Handen. Stojanovski developed a research called Urbanism for Multimodal Transportation Performance Certificates (MTPC) for Buildings and Neighbourhoods, where he uses three methods to assess multimodality in Handen. Figure 34 illustrates the results for the variables that were assessed. The variables used were: access to quality transit, housing and jobs proximity, compact development, reduced parking footprint, transit facilities, access to civic and public space, bicycle facilities, walkable streets, mixed use neighbourhoods, connected and open community, transportation demand management and access to recreation facilities. In this case the heatmaps show the scoring results of the variables in Handen. Figure 35 shows in detail the results for walking also using heatmaps. This research showed that the majority of the area is classified as “somewhat walkable”, whereas some areas were classified as “very walkable” and “walkers paradise”.

Figure 32 Haninge Kommun density source (Stadsutvecklingsplan 2016)

Figure 33 Haninge Kommun Mixed land use source (Stadsutvecklingsplan 2016)
With the new population arriving to live in Handen is necessary to plan sustainable neighbourhoods that will support fossil fuel free mobility options as well as urban structures that reduce the need for private car travel for citizens. These objectives can be reached with a consistent and long-term planning, including principles developed within the Transit Oriented Development (TOD) framework. TOD is a theoretical and practical framework that promotes higher densities, mixed of land use and the extensive offer of sustainable mobility choices. For those reasons is important to implement extensively the use of the TOD standard 3.0 among municipalities in Sweden, so it could be used as a useful tool to plan a more sustainable urban growth.

In this case, the ITDP indicators were used into the Swedish urban context. To strengthen the incorporation of Transit Oriented Development principles into Swedish cities could help at aim to lower the car use through planning and designing urban spaces where citizens can easily use and access different mobility alternatives other than private vehicles. Is important that a wide range of actors such as the civil society, private companies, NGOS and different governmental agencies contribute to build sustainable mobility alternatives for citizens.

As the ITDP assessment criteria results in the classification of the level of inclusion of the Transit Oriented Development principles in a specific area, it was important to implement the evaluation system to assess a specific area in Sweden.
The specific area of study was chosen according to the recommendation of the TOD standard regarding the walking proximity of a transit station. “We recommend 500 meters as optimum, and no more than 1000 meters of actual walking distance, including all detours. A distance of 500 meters represents about a 10-minute walk” (ITDP, 2017). Therefore, the area of study chosen for the assessment is a 500 meters buffer around the pendeltåg station of Handen. Subsequently, the TOD standard 3.0 was implemented in Handen, in Haninge municipality in Sweden. The following figure shows the area of study:

![Figure 36 Location area of study source (RUFS 2018)](image)

### 4.2 Results

The following section shows the results of the assessment of each one of the TOD indicators around Handen’s pendeltåg station. The indicators are presented and explained according to each variable. The method of measurement and results are described.

**WALK**

**1A1 Qualifying walking segments**

To perform the evaluation of the walking segments, it was necessary to define all the walking segments of the area. In order to do that the official data of walking segments was collected from the municipality. After doing so, that given information was complemented with other walking segments that are being used by citizens to walk around the area. Some field observations were performed to identify the complementary corridors that were identified. After having the inventory of the comprehensive walking segments for Handen, it was important to proceed with the qualification. All segments were classified within qualifying walking segments and non-qualifying walking segments. As stated by the ITDP, qualifying walking segments are those which: “are designed for easy pedestrian access to all abutting buildings and properties on the block frontage segment, (b) be unobstructed and barrier-free for people with disabilities, including wheelchair users and people with low vision, according to local regulations or international standards, and (C) receive street lighting at night that is adequate for pedestrian safety and security” (ITDP, 2017). In this case out of a total of 33,165 meters of walking segments,
85% were classified as qualified. According to this classification, the points awarded to this dimension are: 1 out of 3 possible points. The following table will explain more in detail every non-qualifying segment:

<table>
<thead>
<tr>
<th>Number</th>
<th>Address</th>
<th>Reason</th>
<th>Suggestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anläggarvägen</td>
<td>No sidewalk</td>
<td>Implement sidewalk</td>
</tr>
<tr>
<td>2</td>
<td>Vallavägen</td>
<td>No sidewalk</td>
<td>Implement sidewalk</td>
</tr>
<tr>
<td>3</td>
<td>Eskilsparken</td>
<td>Reduced access</td>
<td>Improve accessibility</td>
</tr>
<tr>
<td>4</td>
<td>Eskilsparken</td>
<td>Reduced access</td>
<td>Improve accessibility</td>
</tr>
<tr>
<td>5</td>
<td>Vallavägen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>6</td>
<td>Söderbymalmvägen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>7</td>
<td>Örnens väg</td>
<td>Sidewalk</td>
<td>Implement sidewalk</td>
</tr>
<tr>
<td>8</td>
<td>Norravägen</td>
<td>Sidewalk</td>
<td>Complement sidewalk</td>
</tr>
<tr>
<td>9</td>
<td>Verktygsvägen</td>
<td>Sidewalk</td>
<td>Complement sidewalk</td>
</tr>
<tr>
<td>10</td>
<td>Söderbymalmvägen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>11</td>
<td>Söderbymalmvägen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>12</td>
<td>Sleipnervägen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>13</td>
<td>Mårdvägen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>14</td>
<td>Rudsjöterrassen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>15</td>
<td>Eskilsparken</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>16</td>
<td>Vallavägen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>17</td>
<td>Eskilsparken</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>18</td>
<td>Eskilsparken</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>19</td>
<td>Vallavägen</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
<tr>
<td>20</td>
<td>Eskilsparken</td>
<td>Lighting</td>
<td>Complement lighting</td>
</tr>
</tbody>
</table>

The following images will illustrate the qualifying and non-qualifying typologies. Figure 37 illustrates one of the segments classified as qualifying, in this walking segment there are elements such as public lighting, sidewalk, no barriers for wheelchairs, traffic lights, crosswalks and refuge passage that contributes to create a safe and accessible pedestrian networks for citizens in Handen (see figure 37). On the other hand, the figure 38, illustrates an example of one of the segments that have been classified as non-qualifying. This segment doesn’t have a sidewalk, also it doesn’t have any element that provides safety for pedestrians to walk and navigate into the area. Also, there is not a continuation of the sidewalk or infrastructure that allows pedestrian traffic (See figure 38). This demonstrates that Handen needs to work on upgrading 20 segments in order to fulfil the TOD principles. Figure 39 shows the GIS result.

![Figure 37 Example of qualifying walking segment in Handen source (Google earth 2019)](image-url)
1A1 Qualifying walking segments
1A2 Qualifying intersections

Within this dimension the quality of crosswalks of the area was analysed. To perform this evaluation, it was necessary to map all the pedestrian intersections of the area. In order to do that, aerial satellite images were used in combination with a study visit of the area to determine the location of all the intersections. After this information was mapped it was classified according to the categories of qualifying and non-qualifying intersections. The criteria of qualifying intersections is detailed by the ITDP as: “(a) are barrier-free for people with disabilities, including wheelchair users and people with low vision, according to local regulations or international standards, (b) measure 2 m or more in width and are demarcated, (c) feature all-accessible refuge islands if crossing more than two traffic lanes, and (d) receive adequate street lighting at night for safety and security” (ITDP, 2017). In this variable it was found that 51 out of the 56 intersections are classified as qualifying. That means that 91% of all the intersections are qualifying crosswalks, which gives Handen 2 points out of 3 possible points. The intersections that were classified as non-qualifying are shown on table 2 (see table 2). The following images will illustrate the qualifying and non-qualifying typologies. Figure 40 shows an example of a non-qualifying intersection. In this case, the segment needs to have a clearer crosswalk for pedestrians (see figure 40). On the other hand, figure 41 shows the example of one of the qualifying intersections. In this case, the crosswalk is clearly marked and there are other safety elements for pedestrians, such as a “refuge-passage” and transit signs. This assessment shows that Handen should focus in enhancing 5 walking intersections in order to aim at higher TODness levels. Map 1A2 shows the GIS result (see figure 42).

Table 2 Non qualifying walking intersections

<table>
<thead>
<tr>
<th>Number</th>
<th>Address</th>
<th>Reason</th>
<th>Suggestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rudsjötarrassen</td>
<td>Missing clear crosswalk</td>
<td>Mark clearly the crosswalk</td>
</tr>
<tr>
<td>2</td>
<td>Parkvägen</td>
<td>Missing clear crosswalk</td>
<td>Mark clearly the crosswalk</td>
</tr>
<tr>
<td>3</td>
<td>Runstensvägen</td>
<td>Missing clear crosswalk</td>
<td>Mark clearly the crosswalk</td>
</tr>
<tr>
<td>4</td>
<td>Anläggarvägen</td>
<td>Missing clear crosswalk</td>
<td>Mark clearly the crosswalk</td>
</tr>
<tr>
<td>5</td>
<td>Vallavägen</td>
<td>Missing clear crosswalk</td>
<td>Mark clearly the crosswalk</td>
</tr>
</tbody>
</table>

Figure 40 Example of non-qualifying intersection in Handen source (Google earth 2019)

Figure 41 Example of qualifying intersection in Handen source (Google earth 2019)
1A2 Qualifying intersections

Figure 42 Qualifying intersections source (GIS layer own work 2019)

1B1 Qualifying public walkways

Within this variable, the public walkways were evaluated. In order to perform this evaluation, it was indispensable to map all the street segments that classified as public walkways. Public walkways are understood as segments that are visually open to the adjacent urban structure. After this first procedure, the segments were classified between qualifying and non-qualifying public walkways. According to the ITDP, the qualifying public walkways are defined as: “the length of ground-floor building frontage abutting public walkways that is visually penetrable. Visually penetrable frontage comprises partially or completely transparent windows and materials along the length of frontage at any point between ground level and 2.5 meters (m) above ground” (ITDP, 2017). The map 1B1 shows the results of the mapping exercise (see figure 43). The following satellite images will illustrate the qualifying and non-qualifying typologies. Figure 44 shows one of the examples qualified as qualifying public walkway (see figure 44). Whereas, figure 45 shows a segment that was qualified as non-qualified public walkway (see figure 45). In this sense is clear that Handen urges to incorporate more visually active infrastructure in order to stimulate pedestrians to walk around the area in more qualifying public walkways.
1B1 Qualifying public walkways

Figure 43 Qualifying and non-qualifying public walkways source (GIS layer own work 2019)

Figure 44 Example of qualifying public walkway in Handen source (Google earth 2019)

Figure 45 Example of non-qualifying public walkway in Handen source (Google earth 2019)
1B2 Visually active public walkways

This variable is related to the previous evaluation process. In this case it is required to count the amount of public entrances along a public walkway to determine in what extent it is a visually active public walkway. If there are fewer than 3 public entrances per a 100-meter block it is classified as a non TODness area. In Handen, it was studied the block that appears on the following image (see figure 46), this block has a total of 5 entrances which would mean the highest classification with 5 points. Nevertheless, the study area doesn’t have more examples of streets that have a higher number of entrances. In this case the study area gets 0 points.

In order to aim at a higher TOD ness level, it is important that Handen’s new developments include more active public walkways, were pedestrians can access the buildings and facilities adjacent to the street. The following figures show some examples of active and non-active public walkways. Figure 47 shows an active walkway in central Stockholm; this example illustrates a visually active frontage and a proximity of the building entrances from the walking segment (see figure 47). This type of urban form contributes to activate public spaces and make pedestrians feel safe and motivated to walk and navigate the space. On the other hand, the figure 48 portraits a segment in Handen that does not meet the visually active requirements. As a consequence, these types of areas are less attractive to pedestrians to use and therefore these spaces tend to be less used and visited by citizens (see figure 48).

Figure 46 Example of visually active public frontage in Handen source (Google earth 2019)

Figure 47 Example of visually active public frontage in Stockholm source (Flikr 2019)
1B3 Walkway segments with qualifying shade or shelter

Within this variable are included the physical structures around the station which purpose is to protect citizens from meteorological conditions of the city. In this case since Handen is located on the northern part of the hemisphere, the sunlight is limited. In order to adapt this measurement to Swedish context it will be analysed in which extent are included physical structures suitable for winter contexts. To do so the winter city guideline from Edmonton Canada was analysed. According to this guide some of the following elements can be used in the urban designed to aim at adapting cities to winter contexts. Figure 49 shows an example of a building which design is adapted to provide suitable winter protection for citizens (see figure 49). Through the revision of the winter guide urban design elements, it was found that this area doesn’t incorporate any of the elements mentioned. The points awarded on this parameter are 0. This area could incorporate some elements like “Incorporate design strategies to block wind, maximize exposure to sunshine through orientation and design, use colour to enliven the cityscape and create visual interest with strategic use of creative lighting” (Edmonton city, 2016) among others. Figure 50 shows the physical elements that represent the principles of winter design (see figure 50). In this way, the urban design of Handen would offer comfortable spaces for citizens to walk around and visit throughout the whole year, including the coldest seasons.
Cycle

2A1 Proximity bicycle network

In order to develop this evaluation process, it was required to overlay the layers of buildings and bicycle network. The buildings layer was retrieved from the Haninge municipality database and the bicycle network was mapped accordingly to the pedestrian pathway map used on the first set variables. After performing the overlay analysis of this layers, it was evident that all buildings were located on a distance not farther than 200 meters from the buildings to the bicycle network. No building entrance is more than 200 meters walking distance to the cycle network. These conditions award the area 1 point. The Maximum walking distance to the cycle network is less than 100 meters, which awards 2 points. Therefore, in this variable Handen obtained the maximum score which is 3 points. In this extent there are no further recommendations to implement in this area. The map 2A1 illustrates the GIS process (see figure 51).

2A1 Bicycle network

![Bicycle network](image)

*Figure 51 Bicycle network source (GIS layer own work 2019)*
2B1 Cycle parking at transit stations

The variable 2B1 parking at transit stations measures the proximity of bike parking to the transit station which refers to the Handen pendeltåg station. In this case it was mandatory to perform an overlay analysis between the layers of bike parking and the railway station of Handen. After performing the analysis, it was apparent that there are two different bike parking modules, which can be considered as sufficient. The modules are located 12 meters and 83 meters away from the station which fulfills the requirement of bike parking within 100 meters around train station. 1 point (which is the maximum score) was awarded to this parameter. Nonetheless, one of the modules is covered whereas the other is not. It is recommended that both parking spaces have a covered area so that bike users can use it all the year around even in winter. The map 2B1 portrays the GIS process (see figure 52). Figure 53 portrays the covered bike parking (see figure 53). In this case it is suggested that the ITDP standard 3.0 establishes more strict parameters that also consider cycle parking quality and not only quantity.

2B1 Cycle parking at transit stations

![Map of bike parking at transit stations](image1)

*Figure 52 Cycle parking source (GIS layer own work 2019)*

![Image of covered bike parking](image2)

*Figure 53 Bike parking module in Handen source (own collection 2019)*
2B2 Cycle parking at buildings

This variable is related to the previous one. It measures into what extent the residential areas around the station are prioritizing bike parking. In this parameter is measured the percentage of buildings that provide ample and secure bike parking. The method to perform this evaluation relies on mapping the buildings that have more than 500 square meters and have a residential use and overlay it with the bike parking mapped information. It was necessary to take a sample area and reduce the amount of buildings from 155 to 28 buildings. After that, it was necessary to do a field study to verify that the buildings had a secure bike parking within 100 meters. The map 2B2 illustrates the total of buildings that was part of the evaluation. Figure 54 shows the buildings that have and have not bike parking (see figure 54). As a result of this combination of methods it was found out that the area has 95% of buildings that have secure and ample bike parking. The score that was awarded in this parameter was 1 which is the highest score. Nevertheless, there is a margin for improvement. Private developers and the governmental actors involved in the construction of residential buildings should prioritize and include secure, ample and enough bike parking spaces for residents. In that way there would be sufficient infrastructure for current and future bike users. Figure 55 shows an example of the lack of bike parking facilities found on the area of study during one on-site observation. On the other hand, figure 56 shows an example of the bike poor parking facilities on one of the buildings of the area.

Figure 54 Cycle parking location on sample area in Handen source (Qgis over google earth image 2019)
Figure 55 Lack of appropriate bike parking on the sample area in Handen source (own collection 2019)

Figure 56 Example of poor bike parking modules in Handen Source (Own collection 2019)
2B3 Cycle access in buildings

This parameter is related to the previous one, it aims at estimating the extent in which the morphology of buildings allows bicycles traffic. In this case the cycle access to buildings is quantified. In order to do that, it was necessary to take a sample area and analyse each one of the buildings. The sample area was the same as the previous parameter. A field study was conducted in order to analyse and quantify the buildings that had bike access. The scoring system suggested to study the bylaws of the buildings in this case, but it was difficult to access to that information, so the method was modified. To evaluate this parameter another spatial analysis was performed. Figure 57 illustrates the total of buildings of the area, highlights the sample area and shows with green dots the location of the cycle access to the buildings (see figure 57). Whereas, figure 58 shows an example of one of the cycle access in one residential area inside the sample area. The results show that 90% of buildings have cycle access.
Connect

3A1 Small blocks

This variable focuses on the analysis of the size of the block. In this case it was important to analyse a smaller sample of the area next to the railway station. The method used to perform the evaluation of this parameter was mapping the blocks of the sample area that was chosen. An inventory of each block was developed with Qgis. The results are that 91% of the blocks are shorter than 150 meters. And the length of longest pedestrian block 235 meters. According to the scoring system, this area was awarded a total of 4 points out of 10 possible. Longest blocks may disincentive pedestrians to navigate the area freely and easily. In this regard, is imperative to underline the importance that Handen designs urban areas with blocks that are no longer than 150 meters, as 100 meters of block size are considered as ideal. These type of urban structures gives pedestrian more direct options to navigate the road system, and therefore contribute to make walking an effective way to transport in Handen. Figure 59 shows the GIS result (see figure 59).

![3A1 Small blocks](image)

*Figure 59 Size of blocks source (GIS layer own work 2019)*
3B1 Prioritized connectivity

The 3B1 point analyses the ratio between pedestrian intersections and motorized vehicle intersections. This parameter intends to estimate into what extent, the traffic planning of the city is prioritizing sustainable modes of transport over vehicles. The method used to perform this evaluation was to make an inventory of all pedestrian intersections and overlay it with the inventory of all motor vehicle intersections. It was found out that there is a total of 172 pedestrian intersections, and a total of 109 motor vehicle intersections. This results in a ratio of 1.577 which awards a total of 3 points out of 5. The number of pedestrian intersections could be increased in order to aim at achieving the perfect score which would mean a ratio of 2 or higher. In this case, urban structures that include pedestrianized boulevards and corridors are highly valued. The street network design by itself could determine the prioritization of sustainable mobility alternatives over motorized vehicles. Figure 60 shows an example of a road network that prioritizes pedestrians over motor vehicle traffic (See figure 60). There are several interesting examples around the world of road networks with a prioritized connectivity for pedestrians. Figure 61 shows the pedestrianized project in Bogota, Colombia which could be taken as an example of prioritization of pedestrians over motor vehicles (see figure61). For example, in this case Handen can increase the pedestrian intersections from 172 to 218 and aim at the highest score in TOD. Also, the area could lower the number of motor vehicle intersections and prioritize pedestrian intersections. This area can still improve pedestrian connectivity through enhancing the already existing road network. The map 3B1 illustrates the GIS map result (see figure62).

![Figure 60 Pedestrian prioritized connectivity source (TOD standard 2017)](image)

![Figure 61 Positive example of pedestrian prioritized road network in Bogota source (Carraueri.e.be 2019)](image)
Figure 62 Pedestrian vs motor vehicle intersections in Handen (GIS layer own work 2019)
Transit

4A1 Walking distance to transit

This variable verifies the walking distance from a transit station to the buildings within a radius of 1000 meters. In this case, it was performed an overlay analysis between the layer of buildings, walking paths and the Railway station. The three red lines represent the three farthest walking distances from buildings to the train station. The 3 segments farthest away are 980, 991 and 1003 meters. In this case, the criteria required is fulfilled. No points are awarded in this parameter. The map 4A1 shows the Qgis result (see figure 63).

Figure 63 Public transport alternatives in Handen (GIS layer own work 2019)
Mix

5A1 Complementary uses

This parameter intends to estimate the weight of each category of land use in the area of study. In order to perform this evaluation, it was necessary to make a general land use map of the study area, and then analyse the sample area in more detail. The sample block was chosen in the area adjacent to the railway station, figure 64 shows the area in which the detail analysis was made (see figure 64). With the aim of finding the complementary uses percentage of the sample block, it is necessary to estimate the total of the square meters on the block and then classify it according to the use. Through the GIS analysis and the revision of the detail plans it was found that 70,5% of the land use is destined to offices, whereas 15,3% is commercial and 14,2% is a parking space. According to the scoring system if the predominant use of the block is between 70 and 80% it is awarded a total of 4 points out of 8. As an example, figure 65 shows a typical sample of a residential block on the area, in this case there are no other diversified land uses (see figure 65). Figure 66 shows the detail map of this building that was used to perform the analysis (see figure 66). The map 5A1 illustrated the GIS result (See figure 67), this map was useful to make a general analysis of the whole area of study. This map exemplifies that most of the areas have a highly predominant land use. In this case, it was shown that the area studied around the railway station could be more diversified regarding land use.

Figure 64 Sample block for complementary uses in Handen source (Google earth image 2019)

Figure 65 Typical residential area in Handen source (Google earth image 2019)
5A1 Complementary uses
5A2 Access to local services

In order to estimate the access to local services it was necessary to overlay the spatial information of the buildings of the study area and the access to local services layer. This parameter requires that only residential buildings are analysed, so the first step was to map the residential buildings. After that, it was required to make the inventory of the local services. The first type of service was food, so all supermarkets, small stores, and restaurants were mapped. After that, the second type of service was mapped including all the schools and kindergartens of the area. Lastly, the hospitals or healthcare centers were mapped. After the overlaying analysis it was found out that 80% of the buildings of the area have access to at least 2 different types of services. According to the scoring system the study area is awarded with 2 points. The map 5A2 illustrates the QIS result (see figure 68). Regarding this parameter, there is space for improvement, the types of services offered in the area could be more diversified and accessible to the residential areas in Handen. Is important that services such as food, are provided in a more extensive way in Handen so that citizens would lower the car use for the shortest trips and would use sustainable transport mobility alternatives.

5A2 Access to local services

Figure 68 Access to local services in Handen source (GIS layer own work 2019)
5A3 Access to parks and playgrounds

This parameter measures the proximity between the buildings of the study area and parks, playgrounds and green areas bigger than 300 square meters. In order to perform this evaluation, it was necessary to map the buildings on the area and then map all the parks, playgrounds and green areas like forest and grass. After that, it was required to map the eligible green areas. All polygons were measured and only the ones that exceeded 300 square meters were included in the analysis. It was found out that 100% of the buildings of the area are located within 500 meters of an eligible park, playground or green area. In this case it was attributed 1 point which is the highest score possible. This parameter can be considered as positive in the study area since it acquired the maximum score. There are no further suggestions regarding the proximity of green areas and the built environment in Handen. The map 5A3 shows the Qgis result (see figure 69).

Figure 69 Access to parks and playgrounds in Handen source (GIS layer own work 2019)
5B1 Affordable housing

This parameter intends to measure the percentage of affordable housing within the area of study. In this case, it was not possible to acquire precise information about the affordable housing with official statistics. So, in order to proceed with the evaluation, the latest information about selling prizes was retrieved from booli.se. The properties that are being sold currently (April 2019) were mapped. Figure 70 illustrates the properties that are being sold, they are classified between different categories: new developments, for sale and final price (see figure 70). A statistical analysis of the data was made in order to find the mean of the sales price. After that, it was calculated which percentage of the house market was below 30% of the mean of the whole area. It was found out that 19% of the house market has a selling price that is below 30% of the mean of the selling price of the area. This awards the area 3 points out of 8 possible points. Is important to point out that affordable housing policies are important to promote social mix and promote social wellbeing. In this case, Handen must work to aim at building projects where the market value would be lower in a higher percentage than what it is nowadays. In order to achieve that, is imperative that multiple types of actors like private developers, civil organizations and municipal governmental agencies partner up to formulate projects were a wider range of market prices are available for citizens that have lower income than others.

Figure 70 Housing units that are being sold source (Booli.se 2019)
5B2 Housing preservation

Within this parameter the objective is to determine the percentage of households that were relocated in the same area of the building site of a new housing project. In this regard, this parameter ranks better the projects in which people are relocated on a site within 250 meters of walking distance from the lot where they were living previously. This condition would give an area a total of 3 points which is the maximum score. Projects that relocate people within a 500 meters walking distance are given 2 points. If the project considers relocating less than 100% of the households within a 500 meters radius, the area is given 0 points. Within the area of study there is an on-going residential project showed in figure 71. In this case it was possible to establish through the interview with one of the planners (Sofia Anesäter) that most of the building space was an empty lot. Nonetheless, there were several households that are planned to be relocated within a 250 meters radius from where they were living before. In this case the study area gets a total of 3 points. In this respect is possible to suggest that future developments relocate 100% of the households living on the area previous to the project within a 250 meters radius. Within this parameter, Handen got the highest score and there are no further recommendations to be made.

Figure 71 New development project in Handen source (Personal collection 2019)
5B3 Business and services preservation

This parameter is similar to the previous one and it has to do with estimating the percentage of business and services that were relocated within a 500-meter radius. The score system gives a maximum of 2 points to those projects that consider the relocation of businesses and services that are present on the area of intervention. In this case, through an interview with the same planner, Sofia Anesäter, it was possible to establish that this area of intervention had businesses or services that are planned to be relocated on-site. So, in this case, the area is awarded a total of 2 points. The following figure shows the businesses that are part of the in-site relocation project (figure 72). As the area of study got the highest score there are no further recommendations to be made.

Figure 72 Commercial uses that will be relocate in the new project source (Google earth image 2019)
Density

6A1 Non-residential density

This variable measures the non-residential density in comparison with a project considered as a best practice. The best practice project is be considered a baseline to evaluate Handen. According to the TOD standard it is required to estimate “(a) the total number of jobs and daily visitors per hectare (this is a superior performance indicator if data is available or can be estimated with accuracy sufficient for comparison), or (b) the non-residential floor area ratio (FAR), as an acceptable alternative” (ITDP, 2017). In this case it was possible to acquire the information related to the floor area ratio. If is found that the non-residential density is higher than the project chosen as the baseline and the density 500 meters around the project is higher as well, this parameter would be awarded 7 points which is the maximum score. On the contrary, if the density is 5% lower than the baseline project the area will get 0 points. In this case the chosen baseline project was Farsta Strand, this area offers similar characteristics as it was built around a pendeltåg station and it is located on the suburban area of Stockholm. Also, there was available enough spatial information to calculate the FAR. Map 6A1 shows the Qgis results for Non-residential density in Handen (See figure 73), the total floor area was divided into the total non-residential area and the result was a FAR of: 0,12. Map 6A2 shows the Qgis results for the non-residential density in Farsta (see figure 74). It was found out that the non-residential FAR in Farsta is 0,45. In this case the non-residential density in Handen is 275% lower than Farsta, according to the evaluation system the area of study would get 0 points. Nonetheless, since the baseline project is an area more populated and closest to Stockholm it should not be completely comparable. Handen was awarded a total of 3 points out of 7 possible. In this case there is a wide range for improvement to densify the non-residential areas around the pendeltåg station, specifically 500 meters around the station.

6A1 Non residential density

Figure 73 Non-residential density source (GIS layer own work 2019)
6A2 Non residential Farsta

Figure 74 Non-residential density in Farsta source (GIS layer own work 2019)
6A2 Residential density

As the previous variable, this parameter intends to compare the study area with a best practice area regarding residential density. The same project was analysed as the baseline project to compare residential density. In order to estimate this parameter, it was required to estimate the dwelling unit density in the study area, then do the same procedure for the baseline project. After that, it was necessary to compare both results. Within this parameter, if the quantity of housing units is higher than the baseline project and the 500 meters radius density is higher than the baseline project, the study area is awarded 8 points. In contrast, if the study area has a quantity of housing units 5% below the baseline project it is awarded a total of 0 points. Figure 75 shows the residential density Qgis result for Handen (see figure 75). It was found out that the residential density FAR for Handen is 0.90. Figure 6A2.1 shows the Qgis results for Farsta residential FAR. It was found out that the residential density FAR in Farsta was 1.19. Handen FAR is 30% lower than Farsta. In this case Handen would get 0 points. However, as the previous variable consideration it was awarded 5 points out of 8 possible, because Handen and Farsta are not completely comparable. Figure 76 shows the Farsta residential ratio Qgis result (see figure 76). Nonetheless, this result shows that Handen needs to increase the residential housing units per hectare to aim at higher TODness levels. It is suggested that Handen increases 31% of the current amount of housing units.
6A2.1 Farsta Residential ratio

Figure 76 Residential density ratio sample area Farsta source (GIS layer own work 2019)
Compact

7A1 Urban site

This whole variable aims at creating compact cities with short commutes. Therefore, this parameter intends to estimate the percentage of developable lots that are being built currently or are in plans of doing so. The first step was to map all the developable lots within the study area. The second step was to map the on-going and future projects planned on those lots. After that, the percentage of developable sites was calculated. In this case, if more than 90% of the developable lots are being developed or are planned to be developed, the study area gets 8 points which is the maximum. On the other hand, if less than 80% of the lots are being developed the study area gets 0 points. Figure 77, provided by Haninge Kommun, was used as the baseline information map to locate spatially the developable lots, ongoing projects and non-developed projects (see figure 77). The map 7A1 shows the result of the GIS analysis (see figure 78). In this case, the study area was awarded a total of 5 points as 87% of the developable lots are part of an ongoing or planned project. Handen could increment its TODness level in this regard by increasing 3% or more of the developable lots on the area and include them in future projects.

Figure 77 Developable sites and on-going projects source (Haninge Kommun 2019)
7A1 Urban site

Figure 78 Developable lots in Handen source (GIS layer own work 2019)
7B1 Transit options

This parameter aims at estimating the transit options that are available within a walking distance of the residential areas. In order to measure that, it was necessary to map all the transit options available on the study area. Then it was necessary to calculate the walking distance from the residential areas. If the area has an additional high capacity transport system, the area is awarded a total of 2 points which is the highest score. The map 7B1 shows the QGIS result (see figure 79). It was found that there are sufficient transit options within the study area, so a total of 2 points were awarded to this parameter. There are bus routes and a pendeltåg station that connects the area with the Stockholm region in an efficient way. Nonetheless, as it has been stated in parameter 4, the construction of other means of public transport are encouraged.

Figure 79 Transit options in Handen source (GIS layer own work 2019)
**Shift**

**8A1 Off street parking**

This parameter intends to decrease of car use. It measures the percentage of land use dedicated to off street parking. The first step was to map and measure all off street parking spaces on the study area. After doing so, it was necessary to measure the rest of the area and therefore estimate how much percentage of the total area is dedicated to parking space areas. If an area has from 0% up to 10% of the total area dedicated to parking area, the study site is awarded with 8 points. On the contrary if the area has more than 40% of the area dedicated to parking spaces it is awarded with 0 points. It was necessary to make the analysis within a smaller sample area due to time limitation. The map 8A1 illustrates the GIS result (see figure 80). In this case, it was found out that 28% of the total area is dedicated to off street parking, in this case Handen gets a total of 4 points. These results show that Handen needs to decrease the off-street parking space destined to cars in at least 18% in order to reach the highest TOD score. These spaces could be used to develop projects that diversify land use and foster sustainable mobility options for citizens to shift away from car dependency.

**Figure 80 Off street parking sample area in Handen source (GIS layer own work 2019)**
8A2 Driveway density

This variable intends to measure the number of driveways per 100 meters of block frontage. In order to measure this parameter, it was necessary to estimate the length of block frontage and divide it by 100 meters. After that, it was required to quantify the number of driveways that meet a walkway in the study area. Lastly the driveway density average was calculated. If the study area has 2 or less driveways per 100 meters frontage, it is awarded 1 point. On the other hand, if the area has more than 2 driveways per 100 meters of block frontage it is awarded a total of 0 points. Also, in this parameter the area of the study was reduced to the same sample area used on the previous variable. In this case after the overlay analysis, it was found that the driveway density is 0.45 driveways per 100 meters of block frontage which awards the area a total of 1 point. The map 8A2 illustrates the GIS result (see figure 81). In this regard, there are no further recommendations as the area reached the maximum score.

8A2 Driveway density

![Figure 81 Driveway density sample area in Handen source (GIS layer own work 2019)](image_url)
8A3 Roadway area

This parameter measures the total area destined for motor vehicles. If the total area of the study site destines 15% or less, it is awarded the highest possible points which are 6. If the area has more than 20% of the area occupied by vehicles it gains 0 points. The methodology of estimating this parameter relies on quantifying the total area of traffic road area and the on-street parking and add them up. After that it was required to measure the total amount of land in the study area. Then it was necessary to calculate the percentage of land “paved for motor vehicle traffic and on street parking” (ITDP, 2017). Figures 82 and 83 shows some examples on how cars occupy the street while parking inside the study area. It was found out that 20% of the area is destined to cars, this awards the area 3 points. The map 8A3 illustrates the GIS result (see figure 84). These results show that Handen has a wide range of improvement regarding decreasing the amount of space destined to cars. In this case Handen needs to lower the total roadway area from 20% to 15% or less in order to achieve the highest TODness level.

Figure 82 On street parking in Handen source (Google earth image 2019)

Figure 83 On street parking in Handen source (Google earth image 2019)
8A3 Roadway area

Figure 84 Roadway area in Handen source (GIS layer own work 2019)
SUMMARY, ANALYSIS, DISCUSSION AND CONCLUSIONS
5.1 Results summary analysis

The following table summarizes the TOD results in Handen. It shows the variables, parameters, maximum score and the points divided by each one of the objectives.

Table 3 TOD results summary in Handen

<table>
<thead>
<tr>
<th>Variables</th>
<th>Objectives</th>
<th>Parameters</th>
<th>Maximum points</th>
<th>Score</th>
<th>Notes/Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>WALK</td>
<td>OBJECTIVE A. The pedestrian realm is safe, complete, and accessible to all</td>
<td>1.A.1 Walkways</td>
<td>Percentage of walkway segments with safe, all-accessible walkways</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.A.2 Crosswalks</td>
<td>Percentage of intersections with safe, all-accessible crosswalks in all directions.</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.B.1 Visually Active Frontage</td>
<td>Percentage of walkway segments with visual connection to interior building activity</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>OBJECTIVE B. The pedestrian realm is active and vibrant</td>
<td>1.B.2 Physically Permeable Frontage</td>
<td>Average number of shops, building entrances, and other pedestrian access per 100 meters of block frontage</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>OBJECTIVE C. The pedestrian realm is temperate and comfortable</td>
<td>1.C.1 Shade &amp; Shelter</td>
<td>Percentage of walkway segments that incorporate adequate shade or shelter elements.</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>CYCLE</td>
<td>OBJECTIVE A. The cycling network is safe and complete</td>
<td>2.A.1 Cycle Network</td>
<td>Access to a safe cycling street and path network.</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>OBJECTIVE B. Cycle parking and storage is ample and secure</td>
<td>2.B.1 Cycle Parking at Transit Station</td>
<td>Ample, secure, multi-space cycle parking facilities are provided at all transit stations.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.B.2 Cycle Parking at Buildings</td>
<td>Percentage of buildings that provide ample, secure cycle parking.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.B.3 Cycle Access in Buildings</td>
<td>Buildings allow interior access and storage within tenant-controlled spaces for cycles</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CONNECT</td>
<td>OBJECTIVE A. Walking and cycling routes are short, direct, and varied</td>
<td>3.A.1 Small Blocks</td>
<td>Length of longest pedestrian block</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>OBJECTIVE B. Walking and cycling routes are shorter than motor vehicle routes.</td>
<td>3.B.1 Prioritized Connectivity</td>
<td>Ratio of pedestrian intersections to motor vehicle intersections.</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>
### OBJECTIVE A. High-quality transit is accessible by foot. (TOD Requirement)

**REQUIRED 4.A.1** Walking Distance to Transit

| Walking distance to the nearest transit station. | Score | Non applicable |

### OBJECTIVE A. Opportunities and services are within a short walking distance of where people live and work, and the public space is activated over extended hours.

<table>
<thead>
<tr>
<th>5.A.1 Complementary Uses</th>
<th>Residential and non residential uses within same or adjacent blocks.</th>
<th>Predominant use is 70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.A.2 Access to Local Services</td>
<td>Percentage of buildings that are within walking distance of an elementary or primary school, a healthcare service or pharmacy, and a source of fresh food.</td>
<td>80% of buildings have access to 2 types of services</td>
</tr>
<tr>
<td>5.A.3 Access to Parks and Playgrounds</td>
<td>Percentage of buildings located within a 500-meter walking distance of a park or playground</td>
<td>100% of the buildings located within 300 square meters from a playground, park or green area.</td>
</tr>
</tbody>
</table>

### OBJECTIVE B. Diverse demographics and income ranges are included among local residents.

<table>
<thead>
<tr>
<th>5.B.1 Affordable Housing</th>
<th>Percentage of total residential units provided as affordable housing.</th>
<th>19% of the house market has a selling price below 30% of the mean of the selling price</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.B.2 Housing Preservation</td>
<td>Percentage of households living on site before the project that are maintained or relocated within walking distance.</td>
<td>100% of the houses were relocated within a 500 meters radius</td>
</tr>
<tr>
<td>5.B.3 Business and Services Preservation</td>
<td>Percentage of pre-existing local resident-serving businesses and services on the project site that are maintained on site or relocated within walking distance.</td>
<td>100% of the local businesses were relocated within a 500 meters radius</td>
</tr>
</tbody>
</table>

### OBJECTIVE A. High residential and job densities support high-quality transit, local services, and public space activity.

<table>
<thead>
<tr>
<th>6.A.1 Non residential Density</th>
<th>Non residential density in comparison with best practice in similar projects and station catchment areas.</th>
<th>FAR Handen: 0,12, 275% lower than Farsta 0,45.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.A.2 Residential Density</td>
<td>Residential density in comparison with best practice in similar projects and station catchment areas</td>
<td>FAR Handen: 0,90. FAR in Farsta 1,19. Handen`s FAR is 30% lower than Farsta</td>
</tr>
</tbody>
</table>

### OBJECTIVE A. The development is in, or next to, an existing urban area

| 7.A.1 Urban Site | Number of sides of the development that adjoin existing built-up sites. | 86% of the developable lots are being intervened |

### OBJECTIVE B. Traveling through the city is convenient.

| 7.B.1 Transit Options | Number of different transit options that are accessible within walking distance | Sufficient transit options within walking distance (2) |
After implementing the scoring system of the TOD assessment, is awarded a total of 57 points to Handen pendeltåg station surrounding area. According to the ITDPs classification, Handen has a bronze TOD level. Bronze level is given to projects that have a score between 56 – 70 points. This classification categorizes Handen in a TOD level, “Bronze-standard TOD indicates projects that satisfy a majority of the objectives of best practice” (ITDP, 2017). Nonetheless, Bronze in the lowest TOD classification. There is a range for development opportunities of specific physical and social conditions that Handen could meet so that in the future it could improve its TODness level.

The variables that influence TODness level are classified as follows from highest to lowest: Mix (25), Walk (15), Connect (15), Densify (15), Shift (15), Compact (10), Cycle (6). Mix stands as the variable with the highest weight on the scoring system. Walk, Connect, Densify and shift hold the same value, followed by Compact and Cycle which is the least influential variable on the scoring system.

After Handen pendeltåg surrounding area assessment, it was found out that Mix, Compact and Cycling, where the best ranked variables. Whereas, Walk, Connect, Densify and Shift are the variables with the lowest score. A higher priority could be given to improve those variables that have higher influence on the TODness level. The following section will explain the results more in detail.

Within the variable mix, Handen got the highest score in the parameter of access to parks and playgrounds as 100% of the buildings where located within a 300 square meters radius from a playground, park or green area. Nevertheless, is important to highlight that plain green areas should not be considered necessarily as parks or playgrounds, is also important to consider the quality of the space. Parks or playgrounds should be set as a space where people can enjoy nature, but also that certain urban furniture and facilities need to be placed in order to make the space attractive for children and adults. Alternatively, within the Mix variable, Handen had the best possible score on the parameter that measures Housing and business preservation. In this respect it is clear that the current development projects incorporate this criteria. However, it could be highlighted that for future developments is important to relocate 100% of the households living on the area previous to the project within a 250 meters radius.

On the other hand, there are several aspects that could be enhanced within the Mix variable. The complementary uses parameter revealed that land use in Handen has low diversification. The assessment performed in the area of study demonstrates that most of the neighbourhoods have a highly predominant land use. There are areas were predominant land use represents more than 70% or 80% of the area. In order to achieve a better TODness level, Handen needs to lower the...
predominant land use up to 50% to 60%, which is categorized as being the ideal percentage. To achieve that standard, Handen needs to diversify 10% of the floor area of the current baseline. Also, the mix of land use can be improved through the development of mixed vertical land use and infill diversification projects around the pendeltåg station. This result could be an important guideline to be incorporated in future developments and further promote mixed land patterns.

Also, the complementary use variable can contribute as well to improve the results on the evaluation of the parameter of access to local services. The results regarding the access to local services revealed that 80% of the buildings of the area have access to at least 2 local services. This could be improved by diversifying the land use in the study area by providing access to at least 3 types of services to 80% of the buildings or higher. Also, is important to highlight the importance of the proximity from residential buildings to certain services such as healthcare facilities, pharmacies, education and fresh food supplies. Within the parameter of affordable housing, it was found out that 19% of the house market has a selling price that is below 30% of the mean of the selling price of the area. In order to aim at the highest score Handen it would need to increase from 19% to 50% or more of housing projects that have a selling price 30% below the mean of the area. Is relevant to point out that in order to achieve this objective is imperative to cooperate between the private, public developers and other housing market stakeholders in order to diversify the housing offer and make it accessible for people with different levels of income.

Other of the highest ranked variables, was Compact. Within compact the parameter of Urban site it was found out that 87% of the developable lots are part of an ongoing or planned project. In this respect, Handen could increment its TODness level by increasing 3% or more of the developable lots that are part of a future project. However, the percentage that needs to be increased is low, and Handen is very close to reach a high compact TODness score. Likewise, is important to highlight that the 500 meters area around the pendeltåg station in Handen should be the priority to develop over other areas. Therefore, unoccupied or undeveloped lots around that area should be prioritized and incorporated in an ongoing or future project so that this area can reach its full potential of development.

Also, within the compact variable, Handen obtained the maximum score in transit. There are currently two transit options, nevertheless, is imperative to underline that there could be offered other public transportation system alternatives for citizens to navigate into the road network. It is known that there is a discussion if weather to implement a tram or BRT route within the area of study (Interview Magnus Runesson). One or both systems are recommended, since it would raise the number of public transit options and connectivity of the transport networks in the area.

On the other hand, the Cycle variable assessment received one of the highest scores. Although it is also important to acknowledge that there could still be improvements. It was found out that the biking parking facilities appear to be enough in number but some of the modules can be upgraded so that they could be adapted for winter conditions. All the bike parking areas located next to the buildings of the study area were already built, but they could be upgraded so that they could be used during winter as well. More specifically, there could be implemented covering structures for bike parking not only in the already built environment but also within the new developments planned in Handen. Also, within the ongoing projects is important to highlight already on-going strategies implemented by Haninge Kommun. Initiatives such as the bike strategy for Haninge aims at stimulating citizens to bike more often and therefore increase the number of bike users which would be the main goal.

In contrast, Walk, Densify, Connect, and Shift are the variables that received the lowest scores. Within the walking variable there are several aspects that could be improved on the study area. Within the parameter of walking segments, there are the 20 non qualifying walking segments that could be upgraded. The specific segments are named in table 1 (see table 1). Mainly the aspect that needs to be improved is lighting and the continuation of sidewalks. Regarding to the parameter of
qualifying intersections, is imperative to upgrade 9% of the existing intersections, the specific intersections are mentioned in table 2 (see table 2). In this case intersections can be upgraded by enhancing crosswalks and public lighting.

Regarding the parameter related to the adaptation to winter conditions, is imperative to focus on the importance of implementing urban furniture and structures that protect citizens from winter conditions so that they can navigate the road network throughout the whole year and incentivize active pedestrian traffic even in winter.

Other of the parameters within walking revealed a weak visually active frontage within the study area. This implies that Handen has an urban structure were buildings are set up not close enough from the street, creating an environment where pedestrians don’t feel attracted to walk around. Handen could improve this by creating blocks were pedestrians feel free to look inside the first floor of the buildings adjacent to the streets buildings areas and feel that the urban infrastructure is a continuation of the street. Through the revision of the TOD standard, it was found out that blocks with the highest scores have up to 5 entrances per every 100 meters. Handen could aim at having 3 or 4 entrances per every 100 meters on a high percentage of the blocks of the area surrounding the pendeltåg station.

As a whole, the pedestrian infrastructure in Handen should provide a better physical structure for citizens so they can use a safe and complete network. Although the area has a comprehensive walkable network, it could be enhanced relating the lighting system, the continuation of the sidewalks, quality of crosswalks and the implementation of winter elements.

Likewise, connect was one of the variables with the lowest scores. It was found out that there are 172 pedestrian intersections and 109 motor vehicle intersections. In order to aim at the highest score Handen must increase its pedestrian intersections to 218 or decrease the motor vehicle intersections. The following map, additional pedestrian intersections shows how the area could increase the number of Intersections (see figure 85). Also, the area could lower the number of motor vehicle intersections and prioritize pedestrian intersections. Consequently, this area can improve pedestrian connectivity through enhancing the already existing road network.

![Additional pedestrian intersections](image)

*Figure 85 Pedestrian intersections proposal source (GIS layer own work 2019)*
Also, within the variable of Connect, small blocks are also an element that needs to be enhanced. After the evaluation of this parameter it was found that the longest block found in Handen had 235 meters which is a very long size of block. This block is 135 meters longer than the ideal block size recommended. This urban structure with long blocks can make people feel less likely to walk. People could feel unsafe or not motivated to walk in longer blocks (Interview Olga Brofileva).

The size of the block is an important attribute that needs to be addressed by different stakeholders involved in building the built environment. The size of the block is a component that can be incorporated into new development but also into already built infrastructure by Infill processes (Curtis, et al., 2009). Is imperative to underline the importance that Handen designs urban areas with blocks that are no longer than 150 meters, as 100 meters of block size are considered as ideal. These type of urban structures gives pedestrians more direct options to navigate the road network, and therefore contribute to make walking an effective way to move in the city.

Likewise, density is one of the variables that Handen needs to improve. As the assessment process intends, is important to compare the FAR (floor area ratio) with a project that is considered a best practice, so that the area could have a reference to compare. Both the residential and non-residential density were substantially lower than the baseline project. To get a higher score of the non-residential FAR than the baseline project, Handen needs to increase it by 276%. And, to get a higher score than the baseline project within residential density, Handen needs to increase the number of housing units by 31%. Overall, the current density level around the station is not in its full potential, but taking into a consideration the future plans for the area, the plans are already including sufficient densification projects around the station. Specifically, as shown on section 4.1 the Stadsutvecklingsplan has examples of densification processes on the area around Handen pendeltåg station (Haninge Kommun, 2016).

Into the same extent, Shift was the variable that had the lowest score. Within the parameter of Roadway area, it was found out that Handen needs to lower the total roadway area from 20% to 15% or less in order to achieve the highest TODness level. This could be done on the short term by implementing non-permanent projects or projects that diversify land use. Regarding the parameter of off-street parking, it was found out that 28% of the total area is dedicated to off street parking. These results show that Handen needs to decrease the off-street parking space destined to cars in at least 18% in order to reach the highest TOD score. This can be reached through an effort to cooperate between different stakeholders. Related to this, Haninge has worked on a comprehensive parking strategy that includes measures to lower the amount of space destined to parking spaces (Interview Olga Borfileva). Also, the current comprehensive plan, contains strategies that aim at lowering the percentage of car use in Haninge by encouraging the use of bikes and pedestrian pathways (Haninge Kommun, 2016).

These results show that Handen has a wide range of improvement regarding decreasing the amount of space destined to cars. But also, there is a challenge within Shifting the mindset of citizens to lower the car use and also re-think the street as an area that is not meant to be occupied by vehicles only. Streets in Handen could be a shared space occupied by other means of transport other than cars. Public transport and sustainable mobility options such as bikes and walking could be further promoted on the municipality so that effective sustainable mobility patterns can be achieved.
5.2 Discussion

Implementing the ITDP standard in Handen was useful to deeply understand the physical and socio-economic conditions that influence Transit Oriented Development principles. It was also, important to understand which variables have higher weight in the evaluation process, so that those variables could be prioritized on future interventions. Adding to that, the evaluation method used to measure the parameters was comprehensive and included eight different variables and 25 parameters, which makes the TOD standard reliable for academical and practical purposes.

Also, the standard was flexible in the sense that it allowed to take sample areas to make it easier for researchers or practitioners to test the method. It also gave alternative measures in case the data collection wasn’t enough to perform a specific parameter. This was the case with the residential and non-residential density, which could be measured by FAR (Floor area ratio) or alternatively by the total number of jobs and daily visitors per hectare. Also, this method was very precise regarding the methods and tools people could use to perform the evaluation. The method gave examples of some of the possible sources of information and also, it gave references to real case projects so that users unfamiliar to the method could contextualize the variable and deeply understand it.

Likewise, the method used was useful to answer the research question by knowing into exactly what extent Handen pendeltåg station and its surrounding area are implementing Transit Oriented Development principles. By using the method, it was possible to score the TODness level of Handen with 57 points, which awards the bronze TOD level. Classifying the TOD level is useful to formulate recommendations on how to improve the given score.

Within the process of implementing the TOD assessment in Handen, there were found some limitations and constraints. First, there are some variables that were non-applicable to Swedish context. Therefore, it is important to clarify that some variables of the standard needed to be adapted according to the context.

Also, it could be discussed that there are some evaluation score rankings that could be understood as too low or to high depending on how they are constructed. For example, it might be possible that the bicycle scoring system has a low baseline for Sweden’s standards. As Sweden is working actively to enhance bicycle traffic and the bike share mode is ranked amongst the highest in Europe along Netherland and Denmark (European Commission, 2005). Subsequently, the high score that Handen obtained could be challenged and the current biking standard could be set up for even higher biking standards.

On the other hand, the variables of complementary land use, densify and connect can represent a higher challenge for Sweden’s context as cities were not built following dense, connected and mix land use patterns. So, on the same extent, diversified land use and denser projects could offer wide opportunities for public and private actors to provide different land patterns to citizens. In Sweden specifically in Handen, urban practitioners have the challenge of designing spaces where people walk or bike more for the shorter commutes using car in a lesser extent. Also, citizens need to find more services within walking distance from their home.

Likewise, the density parameter required the comparison with a baseline project that needed to be considered as a best practice project. In this case it was difficult to find similar projects that had the necessary information available. It was decided to use Farsta Strand as the best practice project. Nonetheless, the limitations in this case have to do with how different these projects are in terms of densification levels. This characteristic made difficult to compare the FAR results in both areas. It was necessary to give a higher score to Handen than the official TOD score ranking, because the FAR in the non-residential and residential was far superior than the one found out in the study area. In this respect, for future analysis it is recommended to find a closer area non further than 2 kilometers away from the study area so the urban tissue is somehow similar and more comparable. And therefore, the results could be more feasible.
Similarly, geographical conditions affected in some sense the assessment of the proximity to local service within the mix variable. Within mix, it was measured the proximity to fresh food sources. It needs to be understood that in not all geographical contexts is reachable to find food classified as “fresh food” next to the residential areas. In this case, the fresh food sources were replaced by restaurants and supermarkets found around Handen. Fresh fruits and vegetables can be found in Sweden depending on the season, and they are not all placed in street markets as the TOD standard suggested. Street vendors are not common in Sweden due to weather and regulation conditions. The easiest and more accessible point to buy fresh fruits and vegetables, dairy products or meat are the supermarkets. In this case the parameter needed to be changed and adapted. The TOD standard did not offer an alternative data source in this case, so the parameter was modified according to the information that was available.

In the same way, the affordable housing concept is not universal. Each country sets an affordable housing standard that best fits its socioeconomic system. In this case, the ITDP recommendation was to follow the standard which would be 30% lower of the mean of the housing selling price. This parameter could be revised more carefully for Sweden’s case, as land prices and construction costs in housing projects are more expensive and scarcer than in other areas of Europe (Mundus international, 2018). But on the other hand, it shows that there is a wide range of improvement compared to the ITDP’s baseline standard. In this sense, if the selling price of a house determines the social mix of an area, and if only the richest people can buy the housing units in one specific area the social mix will most likely be low. In this case, this parameter intends to encourage also social mix. Handen could have more housing affordability offers for its citizens which is a goal that can be addressed by different stakeholders involved on the real estate business.

Also, there was some data that was difficult to find or non-existent, that was the case with the variables of affordable housing. In this regard the parameter had to be measured accordingly to the TOD standard 3.0 suggestions. As for the inventory of some of the walking paths, bike parking and off-street car parking the spatial information had to be complemented by the researcher as it was not found on the official datasets.

On the same extent, there were limitations regarding the time frame of the master thesis. As the research was developed in 20 weeks, there were some parameters that needed to be measured by sample areas in order to be able to follow closely the standard quality and criteria that needed to be used. This may represent a constraint in terms of the completeness of the analysis of six of the parameters that were assessed. Specifically, the following parameters were evaluated through sample areas: 2b2 cycle parking at buildings, 2b3 cycle access in buildings, 3a1 small blocks, 5a1 complementary uses, 8a1 off street parking and 8a2 driveway intensity. Nevertheless, within the TOD standard it was recommended to take sample areas in some or most of the indicators in order to contribute to the efficiency of the method. Nevertheless, this factor demonstrates a constraint regarding the completeness of the standard. It can be recommended that the TOD standard be stricter in that sense and allow to use sample areas only in a limited number of parameters.

Also, due to the time constraints it was not possible to further implement the TOD assessment to other pendeltåg station areas in Haninge. It would have been useful to apply this evaluation assessment to stations such as Jordbro, Västerhaninge, Tungelsta or Vega and then compare the results. The section of future research explains this further.

Likewise, choosing a specific study area was a constraint in the sense that all the information that was geographically outside the study area was not included on the analysis. So, if there were any characteristics or assets relevant outside the study area they were not taken into consideration. For example, within the parameter of access to local services within the mix principle it was found out that 80% of the buildings have access to 2 of the three different types of local services that were mapped. In this case it is possible that since only the services inside the area of study were studied, other services on the surrounding area were excluded of analysis. So that could mean that if there are other services offered around the borders
of the area of study, the points awarded could have been higher. That could mean either that there was missing information that was not analysed that could have improved the general score, or that the areas around that were not included could have had even lower score than Handens TODness level. Lastly, is relevant to clarify that Handens TODness score doesn’t necessarily mean that the areas around the study area have similar TODness level.

5.3 General conclusions

This master thesis has investigated the implementation of a Transit Oriented Development assessment in the surrounding area of a Railway station in Sweden. The TOD assessment was performed on a 500 meters radius around Handen pendeltåg station in Haninge, south of the Stockholm region. The following conclusions have been drawn.

The Transit Oriented Development standard used to perform this assessment calculated the performance of eight different variables. Out of the eight variables studied, two stood out as the strongest: Cycle and Compact. (Dittmar & Ohland, 2004) For Cycle it was found out that the biking parking facilities appear to be enough in number as 100% of the buildings are located within 200 meters of a cycle network. As for Compact, it was clear that 87% of the developable lots are part of an on-going or planned project. Also, it was found that there are currently two transit options serving the area, this can be considered as enough options for citizens to navigate into the road network.

On the other hand, the weakest variables were Walk and Connect. For walking it was found out that the walking network needs to be enhanced regarding the quality of few of the walking segments, as well as few of the crosswalks. Likewise, the pedestrian network needs to be adapted for winter conditions. Also, it is clear that Handen needs to incorporate more visually active infrastructure adjacent to public walkways to stimulate pedestrian traffic.

Regarding the Connect variable, it was found out that Handen must increase its pedestrian intersections to improve pedestrian connectivity. Also, it was clear that Handen needs to design urban areas with blocks that are no longer than 150 meters, as 100 meters of block size are considered as ideal. These type of urban structures gives pedestrians more direct options to navigate the road network, and therefore contribute to make walking an effective way to navigate the city.

Applying the TOD assessment in Handen was relevant to understand the factors that can be improved in the area in order to aim at a higher TODness level. Solutions can be framed on the short or on the long term, therefore there are some improvement actions more challenging than others. Within short term actions, is suggested to implement simple physical infrastructure upgrades described on the results and summary parts. Regarding long term actions, some of them require the partnership between different stakeholders to thrive for more structural changes. For example, within Densifying, Mix and Compact is important to notice that the assessment was made in already built infrastructure. Some on these actions can be done as “infill” TOD process on the already built environment (Papa & Bertolini, 2015). Also, TOD principles can be incorporated for newly formulated projects, Conditions such as the size of the block could be taken into a consideration for further developments. Also, visually active frontage is a condition that needs to be incorporated by developers and urban designers. In this sense is indispensable to include private developers and planner authorities into fruitful discussions were these specific conditions are included into already built and newly developments.

There are some variables that have a higher weight on the TOD level. Mixed land use is the variable that most influences the TOD level. Then walking, connect, densify and shift have the same hierarchy. Then compact and finally cycle are the variables that less influence the TOD level. Since Mix and Walking are amongst the weakest variables, and the most
influential within TODness, these are the two variables that should be prioritized in Handen. Making an area more walkable, mix, attractive and safe for pedestrians contributes immensely to reaching a higher TODness level.

It is important to understand that the TOD is a standard to measure the TODness level of an area, but it also needs to be adapted depending on the context. TOD standard could be used as a comprehensive planning tool to aim at promoting sustainable mobility options, denser and mixer urban structures. It is a powerful tool that can be implemented by public or private actors to score, evaluate and monitor the TODness level of an area.

5.4 Future research

It would be useful to continue with the research in other areas of Haninge in order to compare the results obtained from Handen’s assessment. It is recommended to further assess the other 4 pendeltåg stations and its catchment areas in Haninge and encourage other municipalities in the region to do so. TODness level in Sweden would be more comprehensive and useful if it would be used as a practical tool for municipalities to monitor TOD progress. Furthermore, once the TODness assessments are implemented it would be important to make the information available published and available for stakeholders, academia and public in general.
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6.4 Interviews

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- Olga Borfileva. 27th March 2019.
- Anders Nordenskjöld. 3rd April 2019.
- Magnus Runesson. 18th April 2019.

Interview guide questions:

- Do you think that the area around the pendeltåg station is accessible for pedestrian transit?
- Do you think that the area around the pendeltåg station is accessible for cycle users?
- What do you know about cycle parking in Handen?
- Do you think cycling and pedestrians are prioritized over cars form the planning point of view? If you do, why?
- Would you say that the predominant use around the station is residential? If you could rank the land use how would you rank them?
- What do you know about affordable housing policies for Handen?
- Within the new development projects, do you know how the relocation of the people living there was handled? Or it was an unoccupied lot?
- Would you say that the density around the pendeltåg station is higher than in other areas of Handen?
- Can you think of an example with a denser residential area around a pendeltåg station?
- Are there any lots that haven’t been developed in the surroundings of the pendeltåg station?
- What do you think of the number of parking areas around the station? Are there too much?